Aviation Psychology: Practice and Research

Edited by

KLAUS-MARTIN GOETERS

AVIATION PSYCHOLOGY: PRACTICE AND RESEARCH

This page intentionally left blank

Aviation Psychology: Practice and Research

Edited by

KLAUS-MARTIN GOETERS
DLR German Aerospace Center

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

First published 2004 by Ashgate Publishing

Published 2016 by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN
711 Third Avenue, New York, NY 10017, USA

Routledge is an imprint of the Taylor & Francis Group, an informa business

British Library Cataloguing in Publication Data
Aviation psychology : practice and research
1.Aviation psychology
I.Goeters, Klaus-Martin
629.1'3252'019

Library of Congress Cataloging-in-Publication Data
Aviation psychology : practice and research / edited by Klaus-Martin Goeters.
p. cm.
ISBN 0-7546-4017-5
1. Aviation psychology. I. Goeters, Klaus-Martin. II. Title.

RC1085.A95 2004
629.132'52'019--dc22

2004004421

ISBN 13: 978-0-7546-4017-2 (hbk)

Contents

Part 4 Human Factors Training

Part 5 Clinical Psychology

Part 6 Accident Investigation and Prevention

List of Contributors

Martin Angerer graduated in aerospace engineering in 1980 and thereafter began a military flying career, flying fighters in the German Navy. In 1987 he joined the Official German Aeronautical Test Centre and became a test pilot working predominantly in the TORNADO program. He joined Fairchild-Dornier in 1997 doing development and certification test work on the 328 Jet. He led the pilot team for the project of the new aircraft 728.

Marc Damitz (M.Sc. in Psychology) studied in the USA and in Kiel, Germany where he graduated in 1998. His career in aviation psychology started at German Aerospace Centre (DLR) in Hamburg where he worked in the selection of aviation personnel for five years. Since 2001 he has worked as a Human Resources Expert for EUROCONTROL in Brussels, Belgium. His research in the field of selection methods focussed on the validity of assessment centers and multiple aptitude test batteries.

Marie-Claude Delsart has an ergonomics education, specialised in Human Reliability. In the JAR-TEL project (funded by the European Commission and described in this book) she was actively involved in management and technical activities on behalf of Sofréavia. Her own expertise in training as well as in safety analysis gave her the appropriate background to develop, on behalf of EUROCONTROL Agency, a behaviour-oriented observation method for the ATM environment (the BOOM project) as a TRM (Team Resources Management) facilitation tool for instructors. She is currently involved as a human factors specialist in the HMI of the A380 cockpit on behalf of AIRBUS France.

André Droog holds university degrees in both aeronautical engineering and psychology of personality. He started his career in aviation in 1973 as a consultant in psychological selection. He developed the selection system for ab-initio trainee pilots of KLM, the Royal Dutch Airline. In 1988 he became the human factors trainer of the KLM Flight Academy, being occupied with the theoretical and practical training of non-technical skills of trainees. He is on the board of the European Association for Aviation Psychology (EAAP) and of the Dutch Human Factors Advisory Group. His publications are about pilot training and the changing role of the airline pilot.

Hinnerk Eißfeldt (M.Sc. and Ph.D. in Psychology) has worked as an aviation psychologist at German Aerospace Center (DLR) in the Department of Aviation and Space Psychology, Hamburg, since 1986 where he is responsible for the selection of air traffic controllers. His scientific work is concerned with aspects of controller selection, focussed on job analysis in ATC, the development and

validation of computerised work sample tests and on the use of biographical data in selection. He is editor of *Staffing the ATM System – The selection of Air Traffic Controllers* (Ashgate, 2002).

Rhona Flin (B.Sc. and Ph.D. in Psychology) is Professor of Applied Psychology, University of Aberdeen and Director of the Industrial Psychology Research Centre. Since 1987, her research team has been investigating the management of safety and emergency response in high risk industries. They have studied pilots' non-technical skills; leadership and safety on offshore installations; team skills and emergency management on nuclear power plants; anaesthetists' and surgeons' non-technical skills. Her books include *Incident Command: Tales from the Hot Seat* (Ashgate, 2002); *Sitting in the Hot Seat: Leaders and Teams for Critical Incident Management* (Wiley, 1996), *Decision Making under Stress* (Ashgate, 1997).

Ronald N.H.W. van Gent (M.Sc. in Aeronautical Engineering) has worked at NLR (Dutch National Aerospace Laboratory) since 1992 – presently as project leader working closely with FAA and NASA on topics such as Data-Link and Airborne Separation Assurance Systems. Both studies involved extensive simulator trials on the NLR full mission Research Flight Simulator (RFS). He holds management positions in several other research and development projects or panels: ONESKY project, Free Flight Working Group – Operational (F2WGO), and CARE-ASAS panel at EUROCONTROL.

Klaus-Martin Goeters (M.Sc. and Ph.D. in Psychology) has been Head of Department of Aviation and Space Psychology at German Aerospace Center (DLR) in Hamburg, Germany since 1986. His professional activities include research on living and working under confinement (underwater habitats, spaceflights), psychological selection of operational personnel (pilots, air traffic controllers, astronauts), transfer of psychological tests to different cultures and the design and evaluation of non-technical skills training. He teaches at the University of Hamburg. He is Board Member of the European Association for Aviation Psychology. Besides numerous articles and technical reports he is the editor of *Aviation Psychology: A Science and a Profession* (Ashgate, 1998).

Zvi Golany (M.Sc.) graduated in 1989 as an industrial psychologist from the Technion - Israel Institute of Technology. He was a consultant for the Canadian Department of Transport on a project aimed at improving the Canadian air traffic controller recruitment and selection system. He has been working at EUROCONTROL since 1996, where he was the co-author of a dozen books on guidelines for selection, manpower planning and career development for controllers. Currently, he is work package leader of FEAST (First European ATCO Selection Test).

Brent Hayward is Managing Director of Dédale Asia Pacific, an Australian-based company providing consultancy services in organisational safety, aviation psychology and human factors. He is a Registered Psychologist, with 25 years

experience in the provision of services and advice to management within the aviation industry. Previously employed with the RAAF Psychology Service, Australian Airlines, and Qantas Airways, Brent's work has included a broad range of selection, training, accident investigation and consulting activities across Australia, Asia, Europe, Africa and the Americas. Brent was the founding President of the Australian Aviation Psychology Association (1991-2000), and also holds membership of the European Association for Aviation Psychology, the Human Factors and Ergonomics Society and the International Society of Air Safety Investigators. He is co-editor of the books: *Applied Aviation Psychology* (Avebury Aviation, 1996), and *Aviation Resource Management, Volumes 1 and 2* (Ashgate, 2000), and sits on the Editorial Board of the international journal, *Human Factors and Aerospace Safety.*

Peter Hecker (M.Sc. and Ph.D. in Electrical Engineering) joined the Institute of Flight Guidance at German Aerospace Center (DLR) in Braunschweig as research scientist in 1989. Initial focus of his scientific work was in the field of automated situation assessment for flight guidance, where he was responsible for several research projects. Later he extended his research activities into the field of cognitive automation on the flight deck covering concepts, systems and procedures of pilot assistance for all phases of flight 'gate-to-gate'. Currently he is head of the department 'Pilot Assistance' and responsible for the Programmatic DLR Core Area 'Aviation Safety and Human Factors'.

Stefan Höft (M.Sc. and Ph.D. in Psychology) graduated at the Universities of Kiel and Bonn with special emphasis on organisational psychology and psychometrics. From 1996 to 2001 he worked as a research associate at the University of Stuttgart-Hohenheim and received his Ph.D. in 2001 for a thesis dealing with personality fundamentals of personnel selection. Since then he has worked as a post-doc research fellow at the Department of Aviation and Space Psychology at German Aerospace Center (DLR), Hamburg. Beside his practical work as a staff member in the DLR selection program for ab-initio pilot applicants he is doing research and development work in the field of behaviour-oriented diagnostics.

Hans-Jürgen Hörmann (M.Sc. and Ph.D. in Psychology) is currently a senior scientist for human factors and safety research in the Boeing Research & Technology Center in Madrid. In 1987, he received his PhD in applied psychology from the Free University in Berlin. He then worked as aviation psychologist at German Aerospace Center (DLR) in Hamburg for 16 years and was involved in cross-cultural research projects on pilot selection and CRM training methods. Most recently, he participated in a European research consortium, which was designing and evaluating a new training program on situation awareness and threat management techniques. He represents the European Association of Aviation Psychology (EAAP) on the Editorial Board of the *International Journal of Aviation Psychology.*

Gerrit Huelmann (M.Sc. in Psychology) graduated at the University of Hamburg with special emphasis on educational and organisational psychology. His thesis was concerned with the development and evaluation of a computerised test of visual perception speed. Since 1999 he has worked at German Aerospace Center (DLR) in Hamburg as aviation psychologist. His main professional and research activities include the assessment of applicants for Lufthansa German Airlines and also international airlines. Due to his interest in computerised testing he is involved in the development, programming and implementation of computerised aptitude tests.

Bernd Johannes (M.Sc. and Ph.D. in Psychology) is working at the Department of Aviation and Space Psychology at German Aerospace Center (DLR) in Hamburg. Since 1976 he has been doing research on evoked potentials (EEG), voice stress parameters and the assessment of the systemic psychophysiological reactivity to psychological load under extreme environmental conditions (space flight, high altitude, long-term confinement). He is principal investigator for a long-term project on the International Space Station (ISS) (Health Lab / Neurolab-2000) and member of the study group 'Psychology and Culture in Long-Duration Space Missions'.

Bernd Lorenz (M.Sc. and Ph.D. in Psychology) joined the Department of Aviation and Space Psychology at German Aerospace Center (DLR), Hamburg in 1986. He developed and applied assessment methods for the selection of aviation personnel (pilots and air traffic controllers). His Ph.D. thesis involved research of human performance in extreme environments (deep sea divers, astronauts). He was Co-Investigator in two German-Russian space missions and Principal Investigator of the 60-day simulated long-term space mission EXEMSI of the European Space Agency. He worked as a postdoctoral research fellow at the Cognitive Science Lab of the Catholic University of America, Washington, DC, for two years where he investigated human performance in highly automated systems. Currently, he works as a human factors specialist at the DLR Institute of Flight Guidance, Braunschweig.

Andrew Lowe (Ph.D.) has been Principal Consultant at Dédale Asia Pacific since March 2001. Before joining Dédale he spent four years as a consultant in the Melbourne office of international human resource consulting company William M. Mercer. Until 1997 he was Senior Psychologist at the Royal Australian Air Force Headquarters Training Command, Point Cook, near Melbourne. Over some 20 years with the RAAF he worked in the areas of aircrew selection and training, selection validation research, and safety and management education. While with the RAAF he also served as human factors specialist on numerous military aircraft accident investigations. Andrew holds an Honours Degree in Psychology from the University of Melbourne, and in 1997 he completed a Ph.D. at Monash University on the relationship between pilot personality and safe operational performance in a military environment.

Peter Maschke (M.Sc. and Ph.D. in Psychology) has worked as aviation psychologist at German Aerospace Center (DLR), Hamburg since 1983. He is responsible for pilot selection for Lufthansa and Austrian Airlines. His main professional and research activities are personality, the predictive validity of pilot selection methods, and the development and application of training programs for Crew-Resource-Management. His Ph.D. thesis was about personality measurement and self-evaluation. Since 1987 he has been a member of European Association for Aviation Psychology (EAAP) and since 1999 has been registered as EAAP aviation psychologist. He had several university teaching positions and has published articles especially about validity, personality, and job requirements.

Ulla Metzger (M.Sc. and Ph.D. in Psychology). From 1997-2001 she conducted research on the human performance consequences of advanced automation systems in aviation at The Catholic University of America, Washington, DC, USA. At Fairchild Dornier, she was the human factors representative in the flight deck design team and also responsible for the human factors certification program for the 728. Presently, she works on human factors issues in current and future (European) railway systems for the German Railways DB.

Paul O'Connor was awarded his Ph.D. from the University of Aberdeen, Scotland (2002) for Team training in high-reliability industries. While employed as a research assistant at Aberdeen University, in addition to being a researcher in the JAR-TEL project funded by the European Community, he also worked on projects to examine the methods UK aviation companies used to evaluate Crew Resource Management (CRM) training, developed CRM training for offshore production teams, and examined the team training requirements of nuclear operations personnel. He currently works as a research psychologist at the U.S. Navy Experimental Diving Unit.

Viktor Oubaid (M.Sc. and Ph.D. in Psychology) graduated at the University of Bielefeld with special emphasis on personality psychology and psychological diagnostics. His thesis was concerned with the development and empirical evaluation of a questionnaire following evolutionary psychological principles. From 1992-1997 he was working as a lecturer in psychological diagnostics at the University of Heidelberg. After that he changed to the University of Halle-Wittenberg for a post-doc position. Since 1999 he has worked at German Aerospace Center (DLR) in Hamburg as aviation psychologist. His main professional and research activities include the coordination of computerised testing at DLR, assessment of applicants for Lufthansa German Airlines and other customers. Due to his interest in computerised testing he is involved in the development and implementation of computerised aptitude tests and coaching programs (e.g. web-based and computer based training).

Yvonne Pecena (M.Sc. and Ph.D. in Psychology) has worked at German Aerospace Center (DLR) in the Department of Aviation and Space Psychology, Hamburg since 1994. She has been involved in pilot selection and personality

research for pilots. During the last years her work was focussed on the implementation and evaluation of assessment-center techniques in the field of aviation. Her thesis was on Assessment-Center approach in pilot selection – an evaluation study. She is currently engaged in the selection of air traffic controllers for DFS, Deutsche Flugsicherung, where she is responsible for behaviour-oriented aspects of selection.

Lucio Polo (Airline Pilot and Ph.D. in Psychology) joined FIAT Flight Test Department as a technical employee in 1963. Then he became military pilot on F86K and F104G with the Italian Air Force. He joined Alitalia in 1970 as S/O, then First Officer and Captain since 1986. He has worked as Type Rating Instructor since 1991 and as Type Rating Examiner since 1995. He is rated on Caravelle, DC9-30, DC8-43, DC10-30, B737, and A320 Family. Since 1993 he has been in charge of Alitalia Human Factors Department. He was Technical Officer for Alitalia in European Community funded projects: COTTRIS, JARTEL, DIVA and ESSAI. He is member of the Board of the European Association for Aviation Psychology (EAAP) and also member of the Crew Professionalism Training Group in EAAP.

Hermann Rathje (M.Sc. and Ph.D. in Psychology) graduated in 1982 as an industrial psychologist from the Technical University of Braunschweig, Germany. He worked as a project manager and co-ordinator in research and development, and in the selection of aviation personnel, in particular Air Traffic Controllers (ATCOs). In 1994 he joined the European Organisation for the Safety of Air Navigation (EUROCONTROL) Headquarters in Brussels/Belgium. He is the manager of the 'Manpower' Sub-Programme that includes the FEAST project, which is the First European ATCO Selection Test package.

Wolfgang Roth (M.Sc. and Ph.D. in Psychology) is a psychological psychotherapist. From 1987-1998 he worked as aviation psychologist at German Air Force Institute of Aviation Medicine GAFIAM in Fürstenfeldbruck; from 1990-1991 he was exchange scientist at Naval Aerospace Medical Research Laboratory, Pensacola, Florida, USA; from 1991-1998 he was Head of the Clinical Branch at GAFIAM; from 1998-2001 he was Head of the Department of Aviation Psychology at the Office of the Surgeon General, German Air Force, Lohmar; since 2001 he has been expert adviser for military psychology at Ministry of Defense, Bonn.

Vyacheslav Petrovich Salnitski (Ph.D. in Engineering) is head of the Department of Psychology / Psychophysiology of the State Scientific Center of the Russian Federation – Institute of Biomedical Problems RAS (IBMP). Since 1964 he has lead numerous research projects for the optimisation of operator activities under extreme environmental conditions and for the development of methods in order to evaluate operator reliability (e.g. for space craft docking on a space station). He is co-chairing the Human Behaviour and Performance Subgroup of the International Space Station.

Fred Schick (M.Sc. and Ph.D. in Psychology) started his career in 1974 as an engineering research psychologist at the Technical University of Braunschweig, Germany. His thesis was about cockpit automation and pilot workload. In 1980 he joined the Institute of Flight Guidance at German Aerospace Center (DLR), Braunschweig for research on concepts and tools for the design and evaluation of man-machine systems in aviation. His main work is in the development and application of methods for the assessment of operational concepts and human/machine interfaces of pilot and air traffic controller support systems. He is head of the Human Factors Department at his institute.

Gideon Singer (Experimental Test Pilot in the Flight Operations Department of Saab Aircraft AB in Sweden) started his career as a fighter pilot before graduating at the Royal Technical Institute in Stockholm and Test Pilot School in the UK. He has worked on developing and certifying commercial aircraft in Europe (Saab 2000, new Saab 340 derivatives and the Dornier 728). He has been performing research in cockpit human factors and also completed his Ph.D. in this area. He has been involved in several committees addressing human factors in cockpit design. At present he is a member of the FAA/JAA Human Factors Harmonisation Working Group working towards the introduction of human factors to the FAR/JAR 25 regulations and supportive material.

Henning Soll (M.Sc. in Psychology) graduated at the University of Kiel, Germany. He started working for German Aerospace Center (DLR), Hamburg in 1998. Since then his main working fields have included pilot selection, simulator testing, and psychophysiology. He is involved in studies for the European Space Agency ESA in which effects of micro-g on body functions are investigated. He was involved in the project ESSAI (Enhanced Safety through Situation Awareness Integration in training), a project funded by the European Community. He has been owner of a private pilot license since 1989.

Dirk Stelling (M.Sc. and Ph.D. in Psychology) graduated at the University of Hamburg with special emphasis on clinical neuropsychology and organisational psychology. His Ph.D. thesis was on teamwork in man-machine-systems. He works at the Department of Aviation and Space Psychology of German Aerospace Center (DLR), Hamburg. His professional activities are focussed on computerised teamwork assessment in selection. He is an expert for aviation personnel who require psychological evaluation due to problems in performance or behaviour. He has been a registered aviation psychologist (EAAP) since 1999 and has been working as a lecturer at universities and in aviation human factors courses.

Oliver Sträter (M.Sc. and Ph.D. in Engineering Psychology) worked for the German Nuclear Regulatory Body, the Institute of Ergonomics and EUROCONTROL in the fields of incident investigation and human reliability assessment. He counselled for the International Atomic Energy Agency (IAEA), the Nuclear Regulatory Commission (NRC) of the United States, the Swiss Regulatory Body (HSK), and the OECD Halden Reactor Project and is a member

of the German Reactor Safety Commission. Main research topics are errors of commission, cognitive errors and modelling, organisational safety and incident evaluations.

Dominique Van Damme studied Industrial Psychology and Educational Science. For fifteen years she worked in safety management and human factors, developing safety training packages for safety managers and counselling major industries in chemistry, food industry, metallurgy; in the field of electricity distribution she was involved in the development of highly automated systems, HMI development, work place design and assessment as well as control room design. She joined EUROCONTROL in 1995 as a human factors expert. Her main domain of activities are cognitive task analysis, team resource management, integration of human factors in the development of new systems, as well as human error and incident investigation.

Preface

Klaus-Martin Goeters

In 1996 the European Association for Aviation Psychology (EAAP) held its 22nd Conference in Sabaudia, Italy. This conference was planned as a basic introduction into the five main areas of Aviation Psychology: Human Engineering, Selection, Training, Psychological Counselling/Intervention and Human Factors Accident Investigation/Prevention. The contributions to the conference were later published to form a basic textbook on aviation psychology. I myself was the editor of this book *Aviation Psychology: A science and a profession* (Ashgate, 1998). Since 1996 aviation psychology in Europe was quite active and a couple of studies and developments came out with interesting results. For this new book *Aviation Psychology: Practice and Research* I have collected papers which have been written in the last five years. Many of the articles were originally presented at the EAAP conferences in Vienna (1998), Crieff (2000) and Warsaw (2002). All these conferences printed their proceedings in the usual way; but several authors insisted on their material being published in a conventional book. These authors hopefully will be satisfied by this book. Other sources for this book are basic research and development reviews and otherwise unpublished material. The book gives a good overview with respect to aviation psychology activities in Europe, but does not claim to be exhaustive. Just as my first book on Aviation Psychology, this book comprises a significant contribution from Australian aviation psychology in part 6 'Accident Investigation and Prevention'. Traditionally, a close relationship exists between Rob Lee and Brent Hayward from Australia on one side and EAAP on the other side. For years these two experts were running the very successful EAAP course 'Human Factors Accident Investigation and Prevention' together with the former EAAP president Kristina Pollack. Brent Hayward is a contributor to this book again.

I have worked for more than 33 years in the field of aviation psychology. During all these years I had some excursions into deep sea diving and manned space flights. These two areas were interesting but one always suffered from low numbers of subjects if one wanted to do systematic scientific research. Contrary to this situation aviation as a well established system is large enough that as a human factors researcher one always finds a sufficient number of persons for investigation. Thus research results can be based on representative samples. To my experience people in aviation are well aware of the importance of human factors since the consequences of its neglect are often quite obviously seen in incidents and accidents. This situation helps to achieve acceptance of the system for proper human factors research.

After my years of work in aviation psychology I am happy to serve the field by producing this book. Its content fits well with my first book on aviation psychology. It follows the same structure regarding the main domains of aviation psychology, but the papers are not repetitions or extensions of the earlier articles. They add substantial new information to what was published before. In Part 1 'Human Engineering' the reader will learn about human centred automation, cooperative and assisting flight guidance systems, and human factors in aircraft certification. Part 2 'Occupational Demands' will present results regarding the occupational demands of pilots and air traffic controllers. Part 3 'Selection of Aviation Personnel' presents information on computerised aptitude testing, personality evaluation and assessment centre approaches in the recruitment of aviation personnel. In this part the reader will also find two contributions on the economic value of psychological selection. The reported cost-benefits by selection are extremely convincing and again underline the importance of this traditional field of aviation psychology. In Part 4 'Human Factors Training' it will become clear that psychological concepts have found their way via crew resource management training into the official world of flight crew licensing. A couple of papers deal with the question of how crew resource management skills can be objectively assessed by systematic rating tools so that training effects become manifest as required by the aviation authority. The demonstration of training effects is also described in a chapter on the validation of crew resource management training. Part 5 'Clinical Psychology' gives information how to deal with problem cases either by psychological evaluation (diagnosis) or by treatment of post-traumatic stress effects which might not only happen to core personnel such as pilots or controllers, but also to other people who might be involved in severe incidents or accidents such as ground staff, passengers or even professional aid personnel. A third chapter deals with the psycho-physiological evaluation of stress effects under regular working conditions (workload measurement). It offers a convincing approach about how to integrate different physiological parameters into meaningful reaction patterns. Part 6 'Accident Investigation and Prevention' refers to the systematic evaluation of incidents or accidents in aviation. The two chapters in Part 6 are complementary to each other, since one is concerned with human error in air traffic control while the other gives an example for a systemic approach in analysing errors of cockpit crews embedded in their organisational environment. Both contributions emphasise that accident investigation methods developed in aviation can be adapted to other industries for the sake of higher system safety.

During the preparation of the book I realised that in many areas experts are using abbreviations as if they are normal words from the dictionary. A latent pretension exists that these abbreviations should be understood by others. This is a habit which should be avoided if one tries to reach readers who are not from a specific field. In this book I followed the classical rule: If an abbreviation is mentioned the first time in a chapter it has to be written in full. On the other hand these short forms will be also mentioned in the *list of abbreviations*. This should help readers who are stepping into the running text.

I would like to emphasise that the work published in the various chapters in this book could only be performed with the support of international European

authorities (European Community DG TREN and EUROCONTROL) or by national organisations (DFS, DLR, IMASSA, NLR, Sofréavia), airlines (Alitalia, British Airways, KLM, Lufthansa) and universities (University of Aberdeen). All these organisations are interested in enhancing the safety and efficiency of the air transportation system and regularly invest all kind of efforts to reach this goal.

I would like to thank all authors for their work; but finally all authors should realise that the hard work of preparing the Camera Ready Copy of the book was solely in the hands of Karen Thomas (DLR – Aviation and Space Psychology, Hamburg). She did an excellent job in shaping the raw material into a nicely looking professional outfit. Thank you, Karen Thomas!

A couple of chapters received a brush up in English. This was very well performed by Diplom-Psych. Mitra Schümann-Sen. Nevertheless, the reader should also realise most authors are not native English speakers. One should be tolerant with their international English. The content of the book should count. I hope the readers who are interested in aviation psychology will take this book as a useful source of information.

This page intentionally left blank

List of Abbreviations

(A)AF	(Army) Air Force
AAIC	Aircraft Accident Investigation Commission
AASD	After Action Stress Debriefing
AATP	Anti-Airsickness Training Program
AC	Assessment Center (1) or Advisory Circular (2)
ACP	Altitude Separation to Closest Point
ACSWG	Air Crew Selection Working Group
ADVISE	Advanced Visual System for Situation Awareness Enhancement
AFCS	Automatic Flight Control System
AFIRA	Automated Fault Identification and Recovery Agent
AFMS	Advanced Flight Management System
AFOQT	Air Force Officer Qualifying Test
AFQ	Acronym for Follow-up Questioning
AFSG	Air Force Sub-Group
AHMI	Airborne Human Machine Interface
AIS	Aeronautical Information Services
AMANDA	Automation and MAN-machine Delegation of Action
AMC	Acceptable Means of Compliance
AMS	Aeromedical Section
ANOVA	Analysis of Variance
ANSP	Air Navigation Service Provider
AOC	Airline Operation Centre
AOT	Autonomic Outlet Type
AQP	Advanced Qualification Program
AS	Assessment Scenario
ASC	Aviation Safety Council
ASDE	Airport Surface Detection Equipment
ASI	Air Safety Improvement
ASVAB	Armed Services Vocational Aptitude Battery
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATHEANA	A Technique for Human Error Analysis
ATM	Air Traffic Management
ATMOS	Air Traffic Management and Operations Simulator
ATP(L)	Airline Transport Pilot (Licence)
ATTAS	Advanced Technologies Testing Aircraft System
ATS	Air Traffic Services
ATSB	Australian Transport Safety Board

BARB	British Army Recruitment Battery
BASA	Bulgarian Aerospace Agency
BASI	(Australian) Bureau of Air Safety Investigation
BOS	Behaviour Observation Scales
BP	Blood Pressure
BS	Benchmark Scenario
CAA	Civil Aviation Authority
CAHR	Connectionism Assessment of Human Reliability
CAIR	Confidential Aviation Incident Reporting
CAMA	Crew Assistant for Military Aircraft
CAMS	Cabin Air Management System
CAO	Civil Aviation Orders
CASA	Civil Aviation Safety Authority
CASSY	Cockpit Assistant System
CAST	Consequences of future ATM for ATCO Selection and Training
CAT	Computer Assisted Testing
CBA	Computer Based Assessment
CBT	Computer Based Training
CCD	Cursor Control Device
CCT	Complex Coordination Test
CDG	Core Drafting Group
CDM	Collaborative Decision Making
CDU	Control Display Unit
CG	Control Group
CHAID	Chi-Square-Aided Automatic Interaction Detection
CISD	Critical Incident Stress Debriefing
CISM	Critical Incident Stress Management
CI(T)	Critical Incidents (Technique)
CMAQ	Cockpit Management Attitudes Questionnaire
CNS	Central Nervous System
CoFoR	Common Frame of Reference
COOPATS	Cooperative ATS
CPL	Crew Resource Management
CRMI	CRM Instructor
CRMIE	CRM Instructor Examiner
CSCW	Computer Supported Cooperative Work
CTA	Cognitive Task Analysis
CWS	Common Work Space
D	Deutschland / Germany
DAC	Dynamic Airtraffic Control Test
DARA	(Former) German Aerospace Agency
DCP	Distance to Closest Point
DCT	Dyadic Cooperation Test

DFS	Deutsche Flugsicherung
DGTREN	Directorate General / Transport and Energy
DLR	Deutsches Zentrum für Luft- und Raumfahrt e. V.
DMT	Defence Mechanism Test
DOS	Disk-oriented Operating System
DSM	Diagnostic and Statistical Manual of Mental Disorders
DSS	Decision Support System
EAAP	European Association for Aviation Psychology
EADS	European Aeronautic Defence and Space Company
EASA	European Agency for Safety in Aviation
EATCHIP	European Air Traffic Control Harmonization and Integration Programme
EATMP	European ATM Programme
EC	European Commission
ECAC	European Civil Aviation Conference
ECG	Electrocardiogram
ECIP	European Convergence and Implementation Plan
ECL	Electronic Check List
EEG	Electroencephalogram
EFIS	Electric Flight Instrument System
EFMS	Experimental Flight Management System
EG	Experimental Group
EMG	Electro-myogram
ENJJPT	Euro NATO Joint Jet Pilot Training
EOG	Electro-oculogram
ERTS	Experimental Run Time System
ESSAI	Enhanced Safety through Situation Awareness Integration in training
ESVS	Enhanced and Synthetic Vision System
F	France
F/E, FE	Flight Engineer
F/O, FO	First Officer
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FASA	Factors Affecting Situation Awareness
FCL	Flight Crew Licensing
FDP	Flight Data Processing
FEAST	First European ATCO Selection Test
FHA	Functional Hazard Assessment
FIS	Flight Information Service
F-JAS	Fleishman - Job Analysis Survey
FMAQ	Flight Management Attitudes Questionnaire
FM(S)	Flight Management (System)
FNPT	Flight and Navigation Procedures Trainer

FOF	Fear of Flying
FOI	Flight Operations Inspector
FOR-DEC	Acronym: facts, options, risks (phase of consideration); decision, execution, check
GAF	German Air Force
GAFSC	German Air Force Stress Concept
GB	Great Britain
GEMS	Generic Error Modelling System
GFT	General Failure Types
GHMI	Ground HMI
GM	General Manager
GND	Ground
GPWS	Ground Proximity Warning System
HAL	Human Assessment Laboratory
HEA	Human Error Analysis
HERA	Human Error in ATM
HF	Human Factors
HFACS	Human Factors Analysis and Classification System
HF HWG	Human Factors Harmonization Working Group
HF StG	Human Factors Steering Group
HLG	High Level Group
HMI	Human-Machine-Interface
HPD	Heart Period Duration
HPL	Human Performance & Limitations
HR	Heart Rate
HRA	Human Reliability Assessment
HRV	Heart Rate Variability
HTMM	Heterotrait-monomethod
I	Italy
IAEA	International Atomic Agency
IATA	International Air Transport Association
IBMP	Institute for Biomedical Problems Moscow
ICA	Instrument Coordination Analyzer
ICAM	Incident Cause Analysis Method
ICAO	International Civil Aviation Organisation
ICC	Intra-Class Correlation
ID	Individualism-Collectivism
IEM	Instructional & Explanatory Material
IFALPA	International Federation of Air Line Pilots Associations
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMASSA	Institut Médicine Aérospatiale du Service de Santé des Armées

IMC	Instrument Meteorological Conditions
IP	Instructor Pilot
IPA	Intelligent Pilot Assistant
IQ	Intelligence Quotient
IR	Instrument Rating
ISO	International Standardisation Organisation
ITMS	Index of Threat Management Strategies
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
JAR- FCL	JAR- Flight Crew Licensing
JAR- OPS	JAR- Operations
JAR- TEL	JAR- Translation and Elaboration of Legislation
JT-FMAQ	Joint Flight Management Attitudes Questionnaire
KASOs	Knowledge, Abilities, Skills and Other Characteristics
KLM	Royal Dutch Airlines
LAME	Licensed Aircraft Maintenance Engineer
LCD	Liquid Crystal Display
LLC	Line / LOS Checklist
LOA	Level of Automation
LOFT	Line Oriented Flight Training
LOS	Line Oriented Simulation
MAU	Modular Avionics Units
MCC	Multi Crew Cooperation
MCDU	Multifunction Control / Display Unit
MDA	Minimum Descent Altitude
MEL	Minimum Equipment List
MMPI	Minnesota Multiphasic Personality Inventory
MORT	Management Oversight and Risk Tree
MSP	Manpower Sub-Program
MTC	Multiple Task Coordination Test
MTHM	Monotrait-Heteromethod
MTMM	Multitrait-Multimethod
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NATS	National Air Traffic Services
ND	Navigation Display
NDB	Non-Directional (Radio) Beacon
NEO-FFI	Neuroticism - Extraversion - Openness to experiences - Five Factors Inventory
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium - National Aerospace Laboratory (Netherlands)

N/O	Not Observed
NOTECHS	Non-Technical Skills (Assessment)
NPA	Notice of Proposed Amendment
NT(S)	Non-Technical Skills
OASIS	Occurrence Analysis and Safety Information System
OECD	Organisation for Economic Co-Operation and Development
OHP	Overhead Projector (1) or Overhead Panel (2)
OJT	On the Job Training
OPQ	Occupational Personality Questionnaire
OPS	Operations
OPT	Optical Perception Test
PARTI	Pilot Display of Air Traffic Information
PATS	Psychophysiological Assessment Test System
PAV	Psychophysiological Activity Vector
PC	Personal Computer
PCA	Principle Component Analysis
PCI	Personality Characteristics Inventory
PD	Power Distance
PD/2	Phare Demonstration 2
PDA	Personal Digital Assistant
PF	Pilot Flying
PFD	Primary Flight Display
16 PF(T)	16-Personality Factors (Test)
PHARE	Program for Harmonizated ATM Research in Eurocontrol
PIC	Pilot in Command
PNF	Pilot Not Flying
PPL	Private Pilot Licence
PRF	Personality Research Form
PSA	Probabilistic Safety Assessments
PSM + ICR	Propulsion System Malfunction plus Inappropriate Crew Response
PSW	Parasuraman-Sheridan-Wickens-Model
PTT	Pulse Transition Time
PTSD	Post Traumatic Stress Disorder
PUS	Permissible Unserviceability Schedule
PVD	Para-Visual Display
RA	Resolution Advisory
RAAF	Royal Australian Air Force
RAF	Royal Air France
RCT	Rudder Control Test
RG(T)	Repertory Grid (Technique)

RPT	Regular Public Transport
RR	Riva-Rocci
SA	Situation Awareness
SACHA	Separation and Control Hiring Assessment
SAGAT	Situation Awareness Global Assessment Technique
SC	Space Craft
SCL	Skin Conductance Level
SCR	Skin Conductance Response
SD	Standard Deviation
SDS	Spatial Disorientation Simulator
SFINCSS	Simulation of a Flight of International Crews on Space Station
SHAPE	Solutions for Human Automation Partnership in European ATM
SIA	Singapore Airlines
SIAM	Systemic Incident Analysis Model
SIM	Simulator
SLOA	Stakeholders Line of Action
SMGCS	Surface Movement Guidance and Control System
SOF	Student Orientation Flight
SOFREAVIA	Société Francaise d' Etudes et de Realisations d' Equipments Aéronautiques
SOP	Standard Operating Procedure
SPAM	Situation Present Assessment Method
SPSS	Statistical Package Social Sciences
SQL	Search and Query Language
SSA	Shared Situation Awareness
STANINE	Standard Nine (Scale)
STF	Selection Task Force
SWAT	Subjective Workload Assessment Technique
TARMAC	Taxi and Ramp Management and Control
TCAS	Traffic and Alert and Collision Avoidance System
TCP	Time to Closest Point
THC(T)	Two-Hand Coordination (Test)
TLX	Task Load Index
TM	Threat Management
TMA	Terminal Area
TOM	Test of Multiple task performance
TQM	Total Quality Management
TRM	Team Resource Management
TSB	Transport Safety Board
TSS	Temperament Structure Scales

UA	Uncertainty Avoidance
UK	United Kingdom
UN	United Nations
US	United States
UT	University of Texas
VDI	Verein Deutscher Ingenieure / Society of German Engineers
VDT	Visual Display Terminal
VERDI	Verhaltensorientierte Persönlichkeitsdiagnostik (Assessment Center Diagnostics)
VHF	Very High Frequency

PART 1
HUMAN ENGINEERING

This page intentionally left blank

Chapter 1

Human-Centred Automation: Research and Design Issues

Bernd Lorenz

Introduction

Operators particularly in the domain of air transportation (pilots, air-traffic controllers) need to process huge amounts of data that emerge in a highly dynamic, distributed, and real-time environment. Operators have to integrate this data into meaningful assessment with respect to their task goals and transform this into efficient and coordinated action. Automation technology has proven successful at compensating for constraints imposed by human vulnerabilities and limitations in information processing and at augmenting the overall system performance in terms of safety and efficiency. The expected increase in air travel and the resulting increasing demand on a more efficient use of air transportation resources (airspace, airports) are crucial driving forces for a comprehensive innovation of air traffic management and the implementation of advanced automation technology in the United States (Wickens, Mavor, Parasuraman, & McGee, 1998) and Europe (Eurocontrol, 1998). Because of the above-mentioned key characteristic of the working context of pilots and air-traffic controllers their job is foremost cognitive and collaborative. Therefore, the nature of support to be provided by automation should be cognitive and collaborative. In the process of automation some of this activity is transferred to a machine, typically a computer or a network of computers. This creates some sort of sharing, i.e. partitioning the activity between humans and machines introducing a new demand on co-ordination between both agents. Given the capability of today's automation technology more and more aspects of cognitive and collaborative activity can principally be transferred to the machine. Therefore: *'The question is no longer whether one or another function can be automated but, rather, whether it should be.'* (Wiener & Curry, 1980, p. 995). The attempt to base this decision on a careful and deliberate evaluation of the consequences of automation on human performance to enable optimal joint human-machine cognitive and collaborative performance is at the core of a human-centred design of automation.

Billings' Guidelines

Changing the mix of functions that are automated and that are left with the operator often significantly changes the nature of the cognitive and collaborative demands imposed on the operator. One of the most critical changes following automation occurs as a result of depriving the operators of their active involvement in system control activity by allocating them a passive monitoring role (Wiener & Curry, 1980; Metzger & Parasuraman, 2001a). Simultaneously, operators are required to detect automation failures and to resume control in the role of a back-up. There is sound empirical evidence that this demand is associated with serious performance deficiencies. Operators' performance in detecting automation failures in a timely manner may deteriorate by their tendency to over-rely on automation with subsequent negligence to monitor the automated function, which has been referred to as automation complacency (Parasuraman, Molloy, & Singh, 1993; Metzger & Parasuraman, 2001b). But even if the automation failure is detected or is made salient to the operator, poor return-to-manual performance may result, which is also linked to operators being disengaged from actively controlling the system processes. Distanced from the control process operators may lose track of the system state or become unable to project its state into the future, hence, operators lose their situation awareness (Endsley, 1995; Endsley & Kiris, 1995, Endsley & Kaber, 1999). Finally, in the long term, operators may lack sufficient proficiency in their manual skills following a process of decay known to be associated with disuse. This may seriously limit the accomplishment of back-up or recovery duties when automation fails or cannot handle an off-routine situation. Over-reliance, reduced situation awareness, and de-skilling have been collectively termed 'out-of-the-loop unfamiliarity' (Wickens & Hollands, 2000; Wickens, 2002).

From this follows that keeping the human in the loop has to be the key principle of human-centred design of automation. To put this into the full context of Billings' (1991; 1997, p. 39) guiding principles, human-centred design starts with the premise that:

- 'Pilots and controllers bear the responsibility for safety of flight or traffic separation and safe traffic flow, respectively.'

Accepting this premise leads to the axiom that:

- 'Pilots and controllers must remain in command of their flights or air traffic, respectively',

which in turn, leads to the following six corollaries:

1. Both operators must be actively involved.
2. Both operators must be adequately informed.
3. The operators must be able to monitor the automation assisting them.
4. The automated systems must therefore be predictable.

5. The automated systems must also monitor the human operators.
6. Every intelligent system element must know the intent of other intelligent system elements.

In following these guidelines, however, some difficulties arise from the view with which we look at human vulnerabilities and proneness to error (Woods, Johannesen, Cook, & Sarter, 1994; cf. Dekker, 2001). In the technology-centred view, automation is considered, and often sold to the public, as a means to increase safety by bringing down the often-cited 70 to 80 % contribution of human error as a causing factor of aviation accidents. Apart from abetting tendencies to blame the human in the loop, this perspective has been criticised for the misleading expectation that automation should become a kind of a protecting fire-wall between an inherently safe technical system and the inherently unreliable human who has to be constrained in his/her activity. Woods et al. (1994; cf. Dekker, 2001) call for a view that places the origin of error inside the system that has intrinsic contradictions between multiple goals leading to human error as a symptom not a cause. Therefore, it is the human who has to solve these contradictions to create safety. Dekker (2001) provides a series of examples that this active creation of safety is accomplished at the front end of the operator shaping the use of automation artefacts.

The expectation to eradicate human error by automation is also markedly subdued by the experience that automation itself can induce human error (Wiener & Curry, 1980) or that the human encounters new kinds of conflicting goals and, as a consequence, new opportunities for new kinds of human error such as, e.g., mode errors (Woods et al., 1994; Sarter & Woods, 1995). Moreover, the behaviour of automation may become difficult for the operator to understand and anticipate creating what are referred to as automation surprises (Sarter, Woods, & Billings, 1997). This adds a further piece of mode awareness to the compound of the overall situation awareness requirements to be maintained by the operator or the team of operators. Therefore, some of the unexpected problems in the human-automation interaction can be better described as a co-ordination breakdown between two powerful partners (Sarter & Woods, 2000) rather than simply human error.

The Airbus A300 Accident at Nagoya Airport

The fatal accident of an Airbus A300 of China Airlines near Nagoya airport in 1994 that killed 249 of 256 passengers and all 15 crewmembers on board involved such a co-ordination breakdown between the crew and the automation of this aircraft (AAIC, 1996). The co-pilot was performing a normal ILS approach while he inadvertently activated the go-around mode of the flight director, which initiated a nose-up pitch. In order to reacquire the glide slope the co-pilot disengaged the auto throttle and reduced thrust manually. After re-engaging the autopilot it immediately re-entered the go-around mode still selected and commanded a nose-up pitch of 18 degrees, which the crew tried to counteract by commanding the nose down elevator. This conflicted with the autoflight's logic of the go-around mode and its pitch-up commands. In support of the intended go-around manoeuvre the

flight director activated the automated stabiliser system to trim the aircraft to maximum nose-up. However, the stronger the force that the pilots put on the flight control column to activate the elevators, the faster the stabiliser trim responded to counteract the nose-down effort. Forty-two seconds after selecting the go-around mode the autopilots were disengaged again, but the aircraft kept climbing because of the nose-up trim. The aircraft approached stalling speed due to the excessive angle-of-attack that triggered a safety function – alpha floor – that commanded maximum thrust on both engines, which in combination with the maximum nose-up trim increased the aircraft's attitude to 52.6 degrees. Instead of trimming the nose down the captain disengaged the alpha floor function by retarding engine thrust causing the Airbus to stall at 1800 ft.

The description of this accident demonstrates that the human-automation interaction was one of a fight rather than one of collaboration. The second through the sixth corollaries of Billings' principles were strongly violated in that there was no adequate feedback of the automation's activity to the crew rendering its behaviour unpredictable to them and there was no mutual knowledge of intent between the human and the machine agents in the system. Following these and other incidents and accidents pointing to some unexpected problems with advanced automation the majority of system developers and designers accept the necessity of a human-centred approach. However, as already noted, it seems easier to subscribe to it than to translate it into design practice. Sarter et al. (1997) state a gap between human-centred design intentions and actual technology-centred design practice. As Woods (1994, cf. Sarter et al., 1997, p. 1926) has put it 'the road to technology-centred systems is paved with user-centred intentions'. Sarter et al. (1997) attribute the reason for the intention-practice gap to the different perspectives of developers of automation and the people who have to use it. Whereas the developers' view focuses on proving the beneficial impact on human performance, the practitioners view is characterised by the complicating factors that arise under the non-standard circumstances in the operational context. Thus, many automated tools work well under standard conditions but become brittle and clumsy when some unanticipated situations evolve. Therefore, a close link between simulation studies in the laboratory and observations in the field is paramount in the pursuit of human-centred automation research and design.

Human-Centred Automation Policies

There is some debate about the meaning of the label 'human-centred' that will not be dealt with here (see Sheridan, 2000; Winograd & Woods, 1997). In this chapter two definitions of a human-centred design policy or philosophy are adopted, which are in congruence with Billings' guidelines already mentioned.

As to the context of air traffic management automation, Wickens et al. (1998) characterise this as follows:

> The choice of what to automate should be guided by the need to compensate for human vulnerabilities and to exploit human strength. The development of the automated tools should proceed with the active involvement of both users and trained

> human factors practitioners. The evaluation of such tools should be carried out with human-in-the-loop simulation and careful experimental design. The introduction of these tools into the workplace should proceed gradually, with adequate attention to user training, to facility differences, and to user requirements. The operational experience from initial introduction should be very carefully monitored, with mechanisms in place to respond rapidly to the lessons learned from the experiences (p. 13).

This definition conveys several meanings of human-centred design such as exploitation of human strength and user involvement at all stages of the design life cycle.

With a focus on cockpit automation Dekker (2001) states:

> Automation policies are meant to reduce the risk of co-ordination breakdowns across highly automated flight decks, their aim being to match the level of automation (...) with human roles (...) and cockpit display formats (...) (p. 261).

Level of automation, human role, and display formats are three constituents of a human-centred design policy, which will be key issues in the remainder of this chapter. After addressing first the issue of function allocation, which is central to automation design, a specific focus will be placed on the problem of finding appropriate levels of automation. Taxonomies of levels of automation recently proposed in the literature (Endsley & Kaber, 1999; Parasuraman, Sheridan, & Wickens, 2000) and empirical research will be reviewed. Next, by referring to Hoc's (2001) theoretical elaborations around the concept of a Common Frame of Reference, the human, and the system collaborative role is addressed in some more detail.

Human-Machine Function Allocation

Principles

Automation changes the allocation of functions (tasks, roles) to human and machine resources. Traditionally, function allocation has been the task of system designers. Hollnagel and Bye (2000) describe three principles upon which system designers typically base the decision on what function to assign to the human and what to the machine (see also Grote, Weik, Wäfler, & Zölch, 1995). The left-over principle means that the human must do those tasks it is not known how to automate or that are too difficult to automate because the task is too complex, too rare, or too irregular in how it must be implemented. This is technology-centred automation in its strongest sense. It ignores the impact of automation on the operator who is simply not taken into account. Left-over tasks are often boring monitoring tasks such as those left over by high-level automation in process control industries. The operators' competence and motivation is starved, but, ironically, operators are expected to perform efficiently in those difficult and

exceptional off-routine tasks for which the system designer did not find an automated solution (Bainbridge, 1983).

One of the first more explicit function allocation principles is the Fitts list (Fitts, 1951) also known as the MABA-MABA list (Man Are Better At – Machines Are Better At). Allocating to agents those tasks that are best suited to each of them has become a fundamental principle of function allocation. With regard to sensing and perception the human is superior in the detection of minor visual, auditory, and other sensory stimuli and better able to extract meaningful patterns. Human memory is superior in applying efficient search strategies and recalling the essential parts whereas the machine is powerful in the storage and literal reproduction of huge amounts of data. The reasoning capability of machines is deductive, fast and accurate in contrast to human qualities in inductive but slow and more inaccurate type of reasoning. One of the major strengths of the machine is its ability to apply great force accurately and smoothly, which makes it ideal for the allocation of consistent and repetitive sensory-motor action particularly when this has to be coupled with short response times.

Hollnagel and Bye (2000) characterise Fitts list as a compensatory principle of function allocation. It directs system design to the weak and vulnerable aspects of the human and aims at avoiding demands on human performance that go beyond human limitations. It implies two important premises. First, the demands on human performance must be known beforehand in some quantifiable form that enables a comparison with machine performance. Second, some stability over time must be assumed as to the demand as well as to the capabilities of the human and the machine, respectively. The first premise is based on the assumption that humans are comparable to machines. Hollnagel (1999) doubts the adequacy of this assumption, which he refers to as the 'substitution assumption' (p. 31) and, hence, rejects the compensatory principle. He argues that machines are driven by algorithms that prescribe rigid step-by-step procedures. Humans, however, do not perform very well in this manner. Instead, they are guided by the purpose of their actions and able to accomplish a task in several different ways. The substitution assumption is similar to what Billings (1997) refers to as the 'redundancy of parts' paradigm, which is based on the principle of decomposing complex tasks to the smallest replaceable microtask to be assigned to people and machines interchangeably. Although quantification is achieved, applying Fitts principle at this level must ultimately lead to designing the human out of the system since human qualities such as flexibility and creativity elude in the process of task decomposition. Therefore, Billings (1997), and even Jordan (1963) reject the idea of comparing the human with the machine.

Alternatively, humans and machines should be regarded as complementary. For similar reasons Hollnagel (1999) even rejects the concept of function allocation as it focuses on the idea of dividing functions or activities between humans and machines. Based on the cognitive systems engineering approach (Hollnagel & Woods, 1983) he stipulates the need to focus on the joint system itself rather than on the capabilities of its components. This, he claims, directs system design to the more important issue of human-system co-ordination or co-operation in achieving joint goals. He contrasts the principle of function allocation

that corresponds to derive division of labour schemes with a principle of function congruence or function matching that corresponds to questions as to how functions distributed among components of the joint system can be optimally linked to each other. The issue of designing for collaboration is further outlined below.

Yet, system designers have a magnitude of options as to which system functions should be automated and to what extent. Therefore, there exists a need to make such decisions by taking into account human performance consequences. This issue will be addressed in the next section.

Levels of Automation and Human Performance

Defining Automation

Due to the increasing cognitive functions taken on by advanced automation, efficient human information-processing becomes a major role of the operator in the complex human-automation team. Therefore, it is necessary to define automation according to this role and to base the investigation of automation-induced human performance consequences on a human performance model.

Automation can be defined as

> the execution by a machine agent (usually a computer) of a function that was previously carried out by a human (Parasuraman & Riley, 1997, p. 231).

A somewhat more specific definition that emphasises the different functions that automation can take on is

> any sensing, detection, information-processing, decision-making, or control action that could be performed by humans but is actually performed by a machine (Moray, Inagaki, & Itoh, 2000, p. 44).

This definition already explicitly adopts an information-processing view. This view allows envisaging a wide range of external computer support as automation.

A Qualitative Model

Consistent with this view Parasuraman, Sheridan, and Wickens (2000) have recently proposed a model for types and levels of automation as a basis for the evaluation of human performance consequences of automation (see Figure 1.1). This model is subsequently referred to as *P*arasuraman-*S*heridan-*W*ickens (PSW) model. Two assumptions are central to this model with regard to function allocation. First, automation is not an all-or-none phenomenon but can vary along different degrees or levels of automation (LOA). Finding an adequate function allocation becomes a matter of choosing the proper LOA rather than deciding whether or not to automate a task as a whole. Second, proper LOA may differ by processing stage. Processing stages, i.e. types of functions, are classified along a

four-stage sequential human performance model: (1) Information acquisition, (2) information analysis, (3) decision and action selection, and (4) action implementation. Stage 1 automation refers to any kinds of support in attention guiding, cueing, highlighting, or filtering information from the complex environment, which are typically described as automatic alarm or alerting systems. Support by new sensor technologies such as infrared or near-range radar sensors to enhance vision (Hecker & Suikat, 2000) can also be categorised as stage-1 automation. Stage 2 automation supports the integration of information to allow meaningful inferences as to the system state. Examples are technologies of sensor-data fused with terrain-data bases (Krebs & Sinai, 2002; Meyer, 1998) or display integration (Bennett & Flach, 1992). Stage 3 automation relates to support in finding and selecting an appropriate course of action to achieve system goals. This technology belongs to the domain of expert systems. Stage 2 and stage 3 automation define a class of automated systems that are characterised as decision support systems (DSS). Examples are automated tools for conflict detection (stage 2) and resolution (stage 3) in air traffic control such as the Computer-Oriented Metering, Planning, and Advisory System (Völckers, 1991) or the User Request Evaluation Tool (Brudnicki & Mc Farland, 1997). Finally, stage 4 automation supports the execution of actions selected in stage 3.

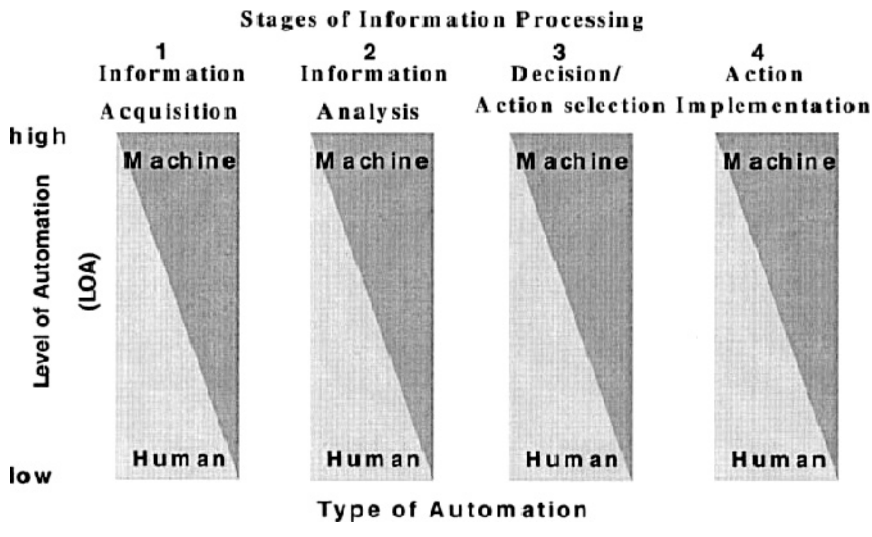

Figure 1.1 Qualitative model to determine the level of automation with regard to four basic human information – processing functions (adopted from Parasuraman et al., 2000)

The PSW model acknowledges the fact that automation does not merely supplant human function but also changes the nature of human activity and

imposes new co-ordination demands for the human operator. Therefore, the human performance consequences of any automation solution are the primary focus of the model. Parasuraman et al. propose an iterative procedure of design evaluation using measures of human performance consequences such as mental workload, situation awareness, complacency, skill degradation, etc. as primary evaluation criteria. After initial types and levels of automation have been established secondary evaluative criteria are applied taking automation reliability and the costs associated with decision and action outcomes into account so as to establish the potential impact of performance consequences identified during the primary evaluative cycle on overall system performance. It has to be shown whether beneficial impacts of automation will unfold, which is unlikely if automation is not sufficiently reliable. Second, a potential impact of negative performance consequences, e.g. a loss of situation awareness associated with a certain type and level of automation, may be acceptable if errors that result from degraded situation awareness are not critical for system goals. The secondary evaluative cycle, therefore, is a risk assessment subjected to the findings of human performance consequences. LOA are not specified on an explicit scale. Parasuraman et al. propose, however, to represent the decision and action selection stage by the 10-point Sheridan-Verplank scale (Sheridan, 1992) depicted in Table 1.1. However, this scale does not only address decision functions but also functions of the action implementation stage. By avoiding being more precise as to the specification of LOA the PSW model is not bound to a specific application domain of automation.

Table 1.1 Levels of automation of decision-making and action implementation functions: The Sheridan-Verplank scale (Sheridan, 1992)

High	10	The computer decides everything, acts autonomously, ignores the human
	9	Informs the human only if it, the computer, decides to
	8	Informs the human only if asked
	7	Executes automatically, then informs the human
	6	Allows the human a restricted veto time before automatic execution
	5	Executes a suggestion if the human approves
	4	Suggests one alternative
	3	Narrows the selection down to a few
	2	The computer offers a complete set of decision/action alternatives
Low	1	The computer offers no assistance, human must take all decisions and actions

Some Empirical Findings on Types and Levels of Automation

There is evidence that automation of decision-making functions, in particular, are associated with potential negative consequences of out-of-the-loop unfamiliarity

mentioned at the beginning of this chapter. Therefore, engaging the operator in decision processes appears to be critical for keeping him/her in the loop. Crocoll and Coury (1990) studied automation in the context of a simulated air-defence task. They compared two types of automation. The first provided only status information on a target. This can be seen as information automation affecting stage 1 and 2 information processing. The second type involved automatic recommendation to engage a specific target, thus, involved decision automation affecting stage 3 information processing. When automation was reliable both types of automation resulted in superior performance relative to a manual control condition. Differences between types were not found. When automation became unreliable, however, target detection performance was worse with decision than with information automation.

Sarter and Schroeder (2001) studied two implementations of an automatic aid, a status and a command display, that support handling of in-flight icing. Pilots in the status conditions received information about the location of the ice accretion, whereas pilots in the command conditions were given recommendations regarding an appropriate action (power setting, flap setting, and pitch attitude). Consistent with Crocoll and Coury, they found that accurate information from either types of automation resulted in improved handling of the icing encounter relative to baseline with no support. Performance with both displays dropped below baseline when the information was inaccurate and this performance loss was greater in the group supported with the command display. Rovira, Zinni, and Parasuraman (2002) and Rovira, McGarry, and Parasuraman (2002) obtained similar results using the corresponding variations of automation implemented in the Multi Attribute Task-Battery (Comstock & Arnegard, 1992) and a simulated military command and control task, respectively.

Endsley and Kiris (1995) specifically addressed the impact of gradual increases of automation support of decision-making on performance of a comparatively simple navigational problem-solving task. They applied a five-level taxonomy of automation to categorise a simulated expert system that ranged from entirely (1) manual through (2) Decision Support, in which the participant received system recommendations, (3) Consensual Artificial Intelligence, in which the system decided and acted upon participant consensus, and (4) monitored, in which the system decided and acted allowing participant veto to (5) full automation. The experimental evaluation involved probe trials during which automation completely failed and required participants to resume manual control. The interesting finding was that prior to automation failures level-2 situation awareness, which is 'understanding the situation' according to Endsley's (1995) model, was best maintained under the manual condition and poorest under full automation with intermediate levels of automation corresponding to an intermediate level of situation awareness. As a consequence, operators supported with full automation encountered out-of-the-loop performance problems upon a breakdown of the expert system. This was expressed in longer decision times as compared to operators who previously performed the task manually.

Later Endsley and Kaber (1999) proposed a more elaborate level-of-automation taxonomy. Consistent with the concept of automation types of the PSW

model the Endsley-Kaber model differentiates four information-processing roles, which can be performed by the human, the computer, or by both agents simultaneously. They derived a discrete10-level scale from the total of 81 (3 to the power of 4) possible combinations of categories. The scale and associated LOA labels are given in Table 1.2. Endsley and Kaber (1999) applied this taxonomy to examine the hypothesis that intermediate LOA improved performance by moderating mental workload while simultaneously maintaining situation awareness. They used a more complex and dynamic task but the same procedure as Endsley and Kiris (1995) of introducing a complete automation breakdown into normal operation with reliable automation support. Benefits during normal operation were largest when task implementation functions were automated, however, stripping away these functions was also most detrimental to performance when automation failed. Unfortunately, this study could not confirm the straightforward inverse relationship between maintenance of situation awareness during normal operation and the amount of out-of-the-loop performance problems during automation breakdown observed by Endsley and Kiris (1995). Low-level automation produced superior return-to-manual performance, however, situation awareness probed by the Situation Awareness Global Assessment Technique (SAGAT) was higher under higher LOA. Endsley and Kaber speculate that higher LOA freed resources that enabled participants to better prepare for queries of situation awareness.

Table 1.2 Endsley-Kaber taxonomy of levels of automation (Endsley & Kaber, 1999)

Level of automation		Monitoring	Generating	Selecting	Implementing
(1)	Manual Control	Human	Human	Human	Human
(2)	Action Support	Human / Computer	Human	Human	Human/Computer
(3)	Batch Processing	Human / Computer	Human	Human	Computer
(4)	Shared Control	Human / Computer	Human / Computer	Human	Human/Computer
(5)	Decision Support	Human / Computer	Human / Computer	Human	Computer
(6)	Blended Decision Making	Human / Computer	Human / Computer	Human / Computer	Computer
(7)	Rigid System	Human / Computer	Computer	Human	Computer
(8)	Automated Decision Making	Human / Computer	Human / Computer	Computer	Computer
(9)	Supervisory Control	Human / Computer	Computer	Computer	Computer
(10)	Full Automation	Computer	Computer	Computer	Computer

Lorenz, Di Nocera, Röttger, and Parasuraman (2002) studied LOA effects of automated fault-management on operator performance using a complex, dynamic process control task, the Cabin Air Management System (CAMS; Hockey, Wastell, & Sauer, 1998). CAMS simulates some generic features of a spacecraft's life support system in a simplified manner. Five subsystems (O2, cabin pressure, CO2, temperature, humidity) are kept within target states by autonomous controllers. The operator is required to monitor the functional efficiency of the control systems and to intervene in case of system faults by stabilising the system, diagnosing, and repairing the fault. In the extended AUTO-CAMS version, intelligent decision support was implemented by simulating a model-based reasoning agent (Automated Fault Identification and Recovery Agent, AFIRA) that provided fault management (FM) advisories at three different levels of automation (LOA). The advisory at low LOA, the Guide mode, took the form of a computerised fault finding or troubleshooting guide. At medium LOA, the Advisor mode, the advisory system had sensory access to the controlled system and provided model-based fault identification along with a suggested series of steps to manage the fault. At high LOA, the Delegate mode, the system additionally offered to implement these steps subject to operator veto. On the Sheridan-Verplank scale mentioned above (see Table 1.1) these LOA define the levels three, four, and six. The empirical evaluation of human performance consequences involved the experimental paradigm used by Endsley and Kiris (1995) and Endsley and Kaber (1999) by introducing a catastrophic failure of the simulated reasoning agent in approximately 10 % of the trials.

As expected, performance improved when support was reliable. According to the findings of Endsley and Kiris (1995), it was expected that the higher the LOA the more performance should decrease upon automation failure. The reason for this was hypothesised in the higher amount of cognitive disengagement of operators working at higher LOA prior to the failure. Contrary to this expectation, best performance in terms of shortest fault identification was found when AFIRA acted at the highest Delegate LOA. Intermediate performance occurred at Guide LOA, and worst performance at the intermediate Advisor LOA. This pattern is illustrated in the upper panel of Figure 1.2. The difference between Advisor and Delegate LOA was significant ($p < .05$). Thus, the characteristic out-of-the-loop pattern of poor fault management was not found at the higher Delegate LOA as predicted but at the intermediate Advisor LOA. Based on an analysis of the operators' information sampling and control intervention strategies a distinct difference between support with Advisor and Delegate LOA was found. During reliable support the following pattern was observed (see Figure 1.3). Whereas operators at Advisor LOA significantly ($p < .05$) reduced system-state inspection, operators at Delegate LOA significantly ($p < .01$) reduced control interventions. During AFIRA failure no between-LOA differences were found neither with regard to the amount of control interventions nor to system state inspections. Most probably, these different shifts in the pattern of system state inspection and control intervention during reliable support must be linked to the differences in fault identification during support failure. Thus, disengagement from controlling lower system

processes during reliable support in the Delegate mode appeared to preserve better situation awareness and hence efficiency at the higher supervisory control level.

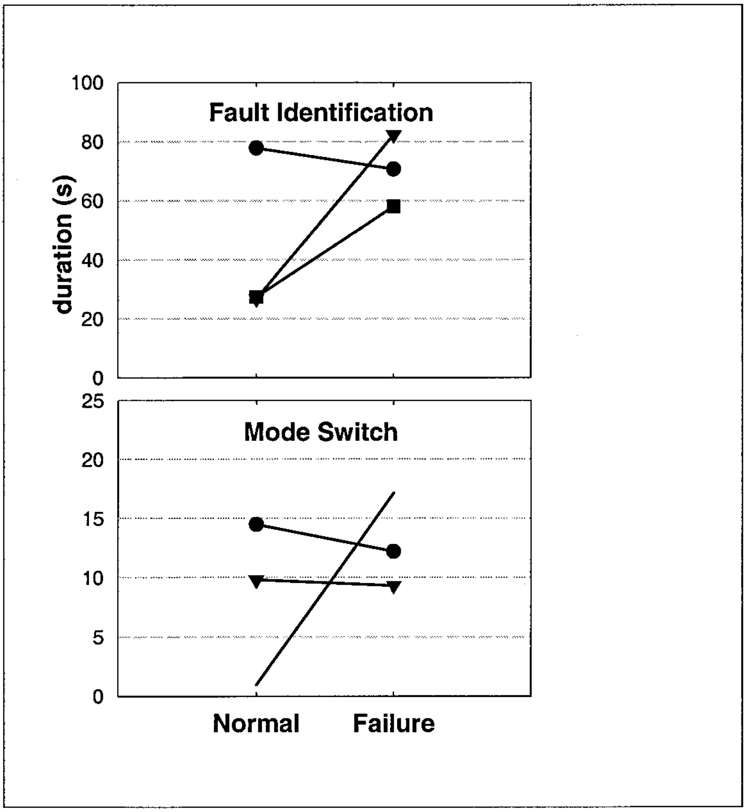

Figure 1.2 Duration of fault identification (upper panel) and timing error of mode switching from fault-mode back to normal-mode settings (lower panel) as a function of normal vs. failed support by the expert agent AFIRA separated for three different levels of automation (LOA) of AFIRA

However, disengagement from control activities at lower system level was likewise associated with performance costs albeit in a less important secondary task. Participants had to switch back system configurations from failure to default settings after repair has been achieved. This mode switch was due exactly one minute after fault repair had been initiated and participants had to monitor the system clock to timely initiate this action. This secondary task was automated at Delegate LOA but remained with the participants at the other two LOA. The results (see bottom panel of Figure 1.2) revealed that the average timing error was lowest under Delegate LOA during normal operation. This is a somewhat trivial

benefit of automation as AFIRA perfectly timed the mode switch and the deviation from a zero timing error resulted from those few trials when operators vetoed against the correct diagnosis of AFIRA and subsequently disengaged the agent. More interesting was the fact that timing the mode switch at Delegate LOA became worst during return-to-manual performance in case of AFIRA failure resulting in a significant LOA by AFIRA operation (normal vs. failure) interaction effect ($p < .05$). This effect can be regarded as a result of an automation-induced loss of the cognitive skill most likely involved in task switching and scheduling.

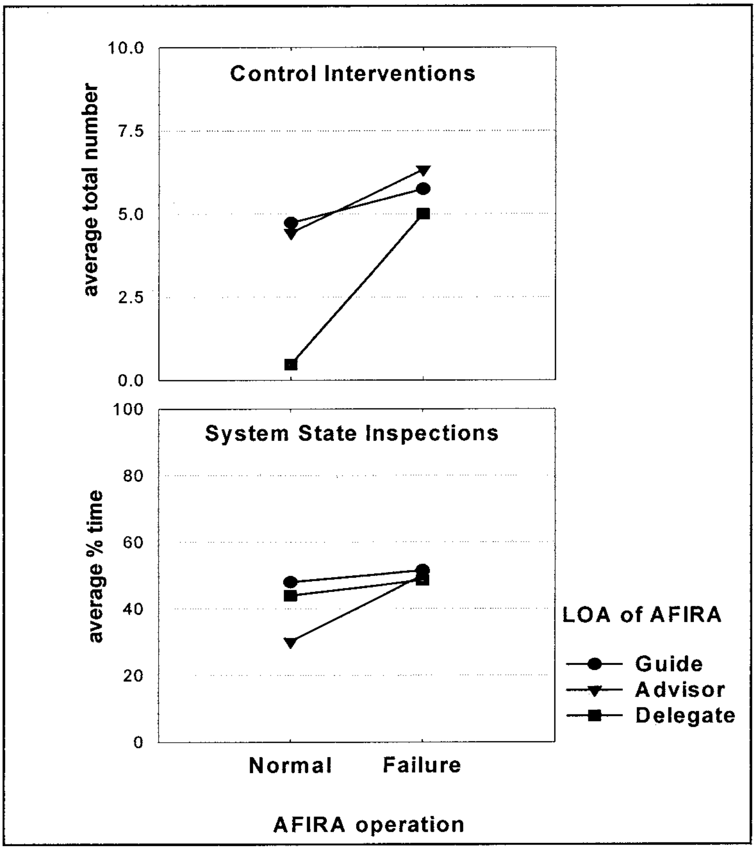

Figure 1.3 Average total number of control interventions (upper panel) and average percentage time displays were activated for system state inspection (lower panel) as a function of normal vs. failed support by the expert agent AFIRA separated for three different levels of automation (LOA) of AFIRA

To explain both return-to-manual effects of, first, the faster fault identification and, second, the less accurately timed mode-switch observed at Delegate in

comparison to Advisor LOA, requires to take the two control loops of AUTO-CAMS into account. Operators at Delegate LOA disengaged from recovery implementation actions and, therefore, were out of the lower-level inner-control loop, whereas operators at Advisor LOA disengaged from fault assessment processes and, hence, were out of the higher-level supervisory control loop. Impaired operator performance in terms of return-to-manual deficits occurred at both LOA in behavioural functions specifically linked to the respective loops, i.e. fault identification time linked to the supervisory control loop and timing the mode switch back to normal settings linked to the inner loop. This suggests that active manual involvement in FM activities per se does not guarantee maintenance of performance in the role as a back-up of failed automation.

Results contradicting the hypothesis that active involvement in the control of a task always supports maintenance of situation awareness have recently been reported by Jentsch, Barnett, Bowers, and Salas (1999) in human-human role allocation. They analysed over 300 civilian incidence reports and found a link between loss of situation awareness and aircrew role assignment. It turned out that loss of situation awareness occurred more frequently, first, when the captain was at the controls than when it was the first officer, second, that the pilot flying was more likely to lose situation awareness than the pilot not flying. They attribute this finding to the twofold burden of captains when engaging in active flight control while simultaneously maintaining the 'big picture' needed to fulfil their role in setting global goals and elaborating problem solving strategies. This explanation is consistent with the one stressed above for the LOA findings made with the AUTO-CAMS micro-world. It is, thus, not surprising that Billings (1991) regards the major benefits of automation for pilots in the cockpit by relieving this twofold burden. 'Automation can lighten this burden on pilots, first by relieving them from the burden of inner-loop control, second by providing integrated information, and third by allowing them to manage at a higher level' (p. 17).

A similar phenomenon in role assignment was also observed in the ATC domain. Vanderhaegen, Crévits, Debernard, and Millot (1994) compared different implementation modes for dynamic task allocation between the human controller and a conflict resolution tool to support en-route air traffic control. In an explicit mode, the human air traffic controller managed the task allocator through a dialog interface. So the controller decided to allocate the task either to himself or to the tool. In the implicit mode, task allocation was managed automatically based on some rules that ensured that easy tasks were allocated to the tool when the overall task demand of the controller was high. Controller performance was best in the implicit mode, although the controllers subjectively preferred the explicit mode. The problem with the explicit mode apparently was the increased workload imposed on the controller by accomplishing the additional task of making a task allocation decision. A subsequent study (Lemoine, Debernard, Crévits, & Millot,1996; Hoc & Lemoine, 1998) revealed that the problem with the explicit mode was not only workload but also a conflicting mismatch in role assignment similar to the one described above. This time, the explicit mode was compared with an assisted explicit mode in which the planning controller was assigned the role of the task allocator who was supported by automatic advisories. Performance

evaluation was in favour of this latter mode, apparently because task allocation management was a strategic task for which the planning controller was better suited than the more tactically engaged executive radar controller.

Summary

Human performance oriented taxonomies of levels of automation such as the PSW or the Endsley-Kaber model provide an integrated view on several kinds of intelligent automation in support of one important human role, which is information processing. These models help to supply the pursuit of both automation policies mentioned above with empirical data. Accumulated evidence, so far, highlight the particular importance of the decision and action selection role for which the human seems to be best suited. In applying these models, however, at least three aspects appear critical.

First, both LOA frameworks do not explicitly address the hierarchical and multi-loop characteristic that is prominent in many complex human-automation systems. The findings with the AUTO-CAMS micro-world have shown that operators can be distanced from the supervisory control loop by engaging them in lower-level inner-loop control. Relieving them from this burden, however, was also associated with out-of-the-loop performance problems. Disengagement from decision-making functions with either loop control was central to both types of performance problems. These point to the presence of a trade-off to be solved by system design by balancing the cost and benefits of selecting LOA across more than one control loop. The search for an optimal intermediate degree along an ordering of levels of automation does not make much sense in this context. The distinction of abstraction levels (Rasmussen, 1983) orthogonal to automation types may be a useful extension for the PSW model.

Second, by focusing on optimal intermediate LOA or by deliberately selecting what to automate in terms of information-processing functions, there is an implicit notion that system design should prevent under- as well as over-automation. This view disregards the importance of the collaborative role of both intelligent agents that results from how they interact with each other. Thus, the question of *what* function should be automated and to what degree must be supplemented by addressing the question of *how* to co-ordinate and communicate the individual human and machine agents' activity during function execution. Similarly, Norman (1990) points out that the problem is not over-automation but inappropriate feedback. However, it has to be emphasised that activities devoted to coordination and communication are also workload drivers and consume time. This fact represents a potential negative cost factor that is difficult to predict during the design of a new system. This may become particularly important for decisions with severe time constraints, e.g. a rejected take-off after the critical V1-speed. For such a decision Inagaki (1999) suggests a level of automation between level-6 and -7 on the Sheridan-Verplank scale to ensure safety: 'The computer executes automatically after telling human' what it will do. No veto is allowed for the human (p. 158). The question whether this level is superior to level-7 (computer executes

automatically, *then* informs the human) to avoid automation surprises needs to be tested.

The third point is closely related to the second. There is a consistent finding in the experimental studies discussed above that transitioning from routine to unanticipated off-routine situations is associated with a performance loss. This problem is known as brittleness (Billings, 1997) and is linked to limitations of the knowledge base of the decision aid. The amount of performance deterioration caused by automation brittleness may be moderated by LOA, however, finding a better function allocation would not solve this problem entirely because automation brittleness emerges from a lack of coordination or lack of feedback between the human and the decision aid during joint problem solving. Thus, the focus should not be to improve function allocation by selecting the LOA associated with the least amount of brittleness. Instead, automation brittleness associated with a certain LOA should be directly addressed by better coupling human and system resources, or in other words, by improving the design for more efficient human-system collaboration.

Designing for Human-System Collaboration

The Need for Common Ground

Consider again the Airbus A300 accident at Nagoya airport. The flight director made several control decisions, e.g. commanding the system stabiliser to trim the aircraft nose-up, against conflicting elevator control inputs of the pilots. It was authorised to do so by the pilot's inadvertent directive to perform a go-around. It did not provide feedback to the pilots as to what it was doing, why it was doing that, and what it was going to do next, which are the key questions to be answered to render an automated system to be observable and predictable (Wiener, 1989). In order to behave like a team player the criteria of observability and predictability must be supplemented by the criterion of directability (Christoffersen & Woods, 2002). A machine agent is good at taking directions if it allows substantive human influence on its activities honouring the role of the human to act in a strategic role. Thus, with the increasing capability of automated systems the questions as to which information the operator should receive when and how it should be displayed along with questions as to how to design the human-machine collaborative activities become central to system design in addition to the issue of function allocation.

Many authors suggest that the human-system interaction should be designed for optimal mutual cooperation or team play (Malin & Schreckenghost, 1992; Sarter & Woods, 2000; Hoc, 2001; Christoffersen & Woods, 2002). As far as human-human team play is concerned training to develop a better aircrew cooperation has been known as Crew Resource Management (Wiener, Kanki, & Helmreich, 1993) and has been implemented by many commercial airlines. The basic CRM principle can be stated as to effectively utilise all available resources (system and humans) to achieve mission goals (safe and efficient flight operations)

and to ensure that all crewmembers operate from a 'common ground' of the actual situation. The notion of common ground means that crewmembers must have mutually held knowledge of the situation. Each crewmember must know what the other crewmembers know and what their intentions are. CRM has shifted the emphasis from training individuals to training crews. Similarly, as already mentioned above, the need for such a shift in emphasis in the context of human-system interaction is proposed by Hollnagel and Woods' (1983) joint cognitive systems approach.

The physical locus of human-machine interaction is the Human-Machine Interface (HMI). Traditional ergonomics has focused on designing the more physical and perceptual-motor properties of the HMI surface structure (colours, font sizes, symbologies, input devices, etc.). However, intelligent problem-solving activities of computers e.g. those involved in advanced decision support systems assisting planning and managing arrivals, departures, and en-route flight trajectories in air traffic control, raise issues of a more profound cognitive nature that has to be approached by system design. If difficulties in human-machine interaction such as automation brittleness or automation surprises are to be avoided human and machine agents must understand each other, i.e. establish common ground and coordinate their action. These issues go beyond traditional HMI design. The challenge is to develop a design concept that facilitates the establishment of common ground. In the civil aviation community in the US and Europe this idea has been known as Collaborative Decision Making (CDM) involving at the most global level the three main air traffic actors, i.e. air traffic service providers, airline operation centres, and airport management. CDM is driven by an effort to reduce delays, accommodate preferences, and avoid risks by improving information exchange and by jointly and pro-actively coordinating the use of airspace resources. In the domain of information technology a new and rapidly growing branch of interdisciplinary research into Computer-Supported Cooperative Work (CSCW) has emerged (Bannon, 2001), which provides a variety of enabling networking technologies to build and maintain common ground in distributed teams. Examples are shared files, use of intelligent agents to gather information in large databases, communication links such as e-mail, chat lines or even virtual co-location. Here it is focused on design issues in the ATM domain, however not at the global CDM level mentioned above but at a more local level to provide one example of how machines can be made more cooperative (see Campion, Brander, & Koritsas (1998) for a design facilitating common ground in the domain of military command and control).

A Framework for Human-Machine Cooperation

Hoc (2001) proposes a framework and an architecture built upon the idea of common ground. He uses the term Common Frame of Reference (CoFoR). The aim is to convey CoFoR to all agents involved as well as to dynamically adapt CoFoR to the individual agents' frame of reference if necessary. This concept has recently been implemented in an air traffic control project called AMANDA standing for Automation and MAN-machine Delegation of Action (Debernard,

Cathelain, Crévits, & Poulain, 2002). Hoc (2001) defines CoFoR as 'a shared knowledge, belief and representation structure between the agents' (p. 519). In an earlier lab-oriented stage of this research Hoc and Carlier (2002) performed an experiment that aimed at a description of CoFoR elements that two radar controllers elaborate and up-date when they have to cooperate. They observed two radar controllers managing the same heavy traffic together in a single sector but with a fixed allocation of aircraft within this sector to each controller. The experiment was organised such that one controller could not send any instruction to an aircraft allocated to the other implying the need to cooperate on shared conflicts. Based on verbal protocol analyses they found that 'cooperation in action' represented only 20 % of the cooperative activities, whereas the majority of 80% was represented by 'cooperation in planning'. This aimed at maintaining CoFoR in order to detect interference between the controllers' individual activities by simple exchange of information and resolving interference by agreement without long explanations due to time constraints. These and further results from other experiments highlight the importance of tight collaboration particularly in decision-making processes. This also points to an interesting consistency with empirical results following the LOA approach in that this research also emphasises the critical role of engagement in decision-making processes to maintain system state awareness. Hoc and Carlier (2002) used their empirical findings on CoFoR maintenance to design automation tools to be integrated in the AMANDA simulation platform.

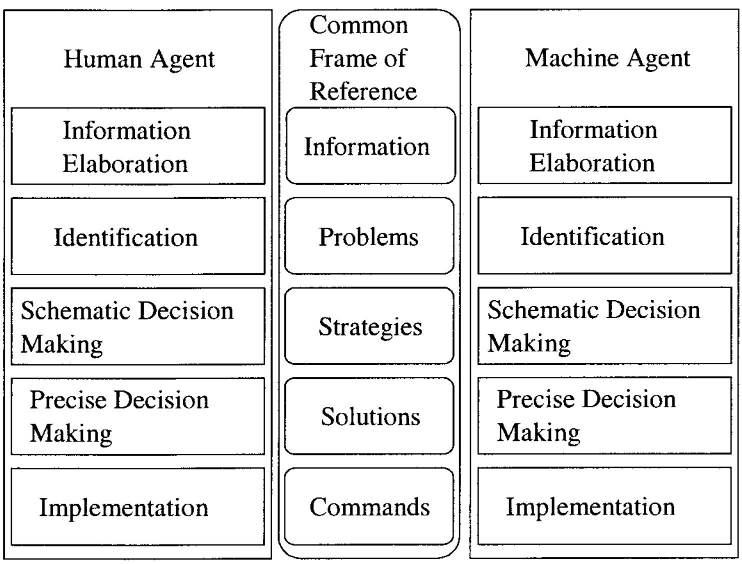

Figure 1.4 Contents of a Common Frame of Reference (cf. Debernard et al., 2002)

The contents of CoFoR are defined around Rasmussens' (1983) decision ladder model that addresses the four fundamental cognitive activities of information elaboration, situation identification, decision-making on strategies and solutions, and solution implementation equivalent to types of automation functions of the PSW model described above (Figure 1.4). In the system architecture, CoFoR is implemented on a machine which is called Common Work Space (CWS). To cooperate, agents pass on the products of the respective activities to form the content of the CWS, which are information, problems, strategies / solutions, and commands enabling a sharing of their own frame of reference. Besides defining the effective contents of the CWS the design of a cooperative human-machine system must allow for activities that, first, up-date and control its contents to achieve consistence with each agent's frame of reference and, second, for activities that manage the interference, i.e. coordinate the interdependent collective activities of agents. Therefore, inconsistencies between CWS content and agent frames of reference must be detected, diagnosed, and resolved. Pacaux-Lemoine and Debernard (2002) describe three forms of solving these inconsistencies that may be used by agents: negotiation, acceptance, and imposition. Negotiation aims at either modifying CWS content or the frame of reference of an agent on the basis of further explanations, which is associated with the largest costs in terms of demanding cognitive, communication, and time resources. Acceptance and imposition are reciprocal in that either an agent updates its frame of reference from the CWS, or opposite to that impose its frame of reference to the CWS. Debernard et al. (2002) further describe how this functionality has been used to integrate decision support tools with CWS interfaces implemented on an operational human-in-the-loop simulation platform.

Concluding Remarks

Increases in the level of automation are inevitably associated with increases in the complexity of automation. This requires a proportionate increase in the feedback automation must provide to its human partners about its activities (Norman, 1990; Christoffersen & Woods, 2002). Human-centred automation policies seek at matching the level of automation with human roles and display formats (Dekker, 2001). This chapter has tried to elaborate the research and design issues implied to accomplish this policy. There is converging evidence from research on human performance consequences of varying levels of automation and research on human-human collaborative activities to maintain a Common Frame of Reference that decision-making processes are key in this regard. Taxonomies of levels of automation along with experimental research on human performance consequences and system design principles elaborated by Parasuraman et al. (2000) guide system design in human-automation function allocation by focusing on the central information-processing role of human operators in advanced human-automation systems. Finding an appropriate match with display formats means finding the corresponding level of cooperation which goes beyond traditional HMI design issues and addresses the second major human role of collaboration. Computer-

supported cooperative work (CSCW) will be one of the key enabling technologies to develop cooperative machines providing a Common Frame of Reference in support of collaborative decision-making. Therefore, these technologies have to further accommodate the cognitive, dynamic, and distributed nature of tasks in the aviation domain and have to keep pace with the technological development of advanced automation. The goal should be to pave the way to human-centred solutions and to avoid getting stuck in human-centred intentions.

Acknowledgements

The author gratefully acknowledges the comments of Ulla Metzger and Serge Debernard on draft versions of this chapter.

References

Aircraft Accident Investigation Commission (1996). Aircraft accident investigation report 96-5, China Airlines, Airbus Industries A300B4-622R, B1816, Nagoya Airport, April 26, 1994, *Ministry of Transport, Japan*. Prepared for the WWW by Sogame, H. & Ladkin, P., July 1996.

Bainbridge, L. (1983). Ironies of automation. *Automatica, 19*, 755-779.

Bannon, L.J. (2001). Toward a social and societal ergonomics: a perspective from computer-supported cooperative work. In M. McNeese, E. Salas, & M. Endsley (eds.), *New trends in cooperative activities: understanding system dynamics in complex environments* (pp. 9-21). Santa Monica, CA: Human Factors and Ergonomic Society.

Bennett, K.B., & Flach, J.M. (1992). Graphical displays: Implications for divided attention, focussed attention, and problem solving, *Human Factors, 34*, 513-533.

Billings, C.E. (1991). Human centred aircraft automation: A concept and guidelines *(NASA Tech. Memorandum 102885)*. Moffet Field, CA: NASA Ames Research Center.

Billings, C.E. (1997). *Aviation automation: the search for a human-centred approach*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Brudnicki, D.J., & Mc Farland, A.L. (1997). User Request Evaluation Tool (URET) conflict probe performance and benefits assessments. Technical Report. McLean, VA: Mitre Cooperation.

Campion, J., Brander, G., & Koritsas, E. (1998). Establishing common ground and competence in team performance. *Proceedings of the RTO Human Factors and Medicine Panel Symposium RTO-MP-004* Collaboration Crew Performance in Complex Operational Systems held in Edinburgh, UK, 20-22 April 1998, pp. 30 /1-4.

Comstock, J.R., & Arnegard, R.J. (1992). The multi-attribute task battery for human-operator workload and strategic behavior research. (*NASA Tech Memorandum No. 104174*) Hampton, VA: NASA Langley Research Center.

Christoffersen, K., & Woods. D.D. (2002). How to make automated systems team players. In E. Salas (ed.), *Advances in human performance and cognitive engineering research, vol. 2*. Amsterdam, The Netherlands: Elsevier.

Crocoll, W.M., & Coury, B.G. (1990). Status or recommendation: selecting the type of information for decision-aiding. *Proceedings of the Human Factors and Ergonomics Society 34th Annual Meeting* (pp. 1524-1528). Santa Monica, CA: HFES.

Debernard, S., Cathelain, S., Crévits, I., & Poulain, T. (2002). AMANDA project: Delegation of tasks in the air-traffic control domain. In M. Blay-Fournarino, A.-M. Pinna-Dery, K. Schmidt, & P. Zaraté (eds.), *Cooperative systems design* (pp. 173-190). Amsterdam, the Netherlands: IOS.

Dekker, S.W.A. (2001). The re-invention of human error. *Human Factors and Aerospace Safety, 1*, 247-265.

Endsley, M.R. (1995). Measurement of situation awareness in dynamic systems. *Human Factors*, 37, 65-84.

Endsley, M.R., & Kaber, D.B. (1999). Level of automation effects on performance, situation awareness and workload in a dynamic control task. *Ergonomics, 42*, 462-492.

Endsley, M.R., & Kiris, E.O. (1995). The out-of-the-loop performance problem and level of control in automation. *Human Factors*, 37, 281-394.

Eurocontrol (1998). *Operational concept document.* Brussels, Belgium: Author.

Fitts, P.M. (1951). Engineering psychology and equipment design. In S.S. Stevens (ed.), *Handbook of experimental psychology* (pp. 1301-1306). New York, NY: Wiley.

Grote, G., Weik, S., Wäfler, T., & Zölch, M. (1995). Complementary allocation of functions in automated work systems. In Y. Anzai, K, Ogawa, & H. Mori (eds.), *Symbiosis of human and artifact.* Amsterdam, The Netherlands: Elsevier.

Hecker, P., & Suikat, R. (2000). Pilotenassistenzsysteme: Ein Beitrag zur Erhöhung der Flugsicherheit. In Zentrum für Verkehr der Technischen Universität Braunschweig (ed.), Automatisierungs- und Assistenzsysteme für Transportmittel. Möglichkeiten, Grenzen, Risiken. *Fortschritt-Berichte VDI, Reihe 12*, Nr. 431, (pp. 132-146). Düsseldorf: VDI.

Hoc, J-M. (2001). Towards a cognitive approach to human-machine cooperation in dynamic situations. *International Journal of Human-Computer Studies, 54*, 509-540.

Hoc, J.-M., & Carlier, X. (2002). Role of a common frame of reference in cognitive cooperation: Sharing tasks between agents in air traffic control. *Cognition, Technology & Work, 4*, 37-47.

Hoc, J.M., & Lemoine, M.P. (1998). Cognitive evaluation of human-human and human-machine cooperation modes in air traffic control. *International Journal of Aviation Psychology, 8*, 1-32.

Hockey, G.R.J., Wastell, D.G., & Sauer, J. (1998). Effects of sleep deprivation and user interface on complex performance: A multilevel analysis of compensatory control. *Human Factors, 40*, 233-253.

Hollnagel, E. (1999). From function allocation to function congruence. In S. Dekker & E. Hollnagel (eds.). *Coping with computers in the cockpit*, (pp. 29-53). Aldershot, UK: Ashgate.

Hollnagel, E., & Bye, A. (2000). Principles for modelling function allocation. *International Journal of Human-Computer Studies, 52*, 253-265.

Hollnagel, E., & Woods, D.D. (1983). Cognitive systems engineering: new wine in new bottles. *International Journal of Man-Machine Studies, 18*, 583-600.

Inagaki, T. (1999). Situation-adaptive autonomy: trading control of authority in human-machine systems. In M.W. Scerbo & M. Mouloua (eds.), *Automation technology and human performance: current research and trend* (pp. 154-158). Mahwah, NJ: Erlbaum.

Jentsch, F., Barnett, J., Bowers, C.A., & Salas, E. (1999). Who is flying this plane anyway? What mishaps tell us about crew member role assignment and air crew situation awareness. *Human Factors, 41*, 1-14.

Jordan, N. (1963). Allocation of functions between man and machines in automated systems. *Journal of Applied Psychology, 47*, 161-165.

Krebs, W.K., & Sinai, M.J. (2002). Psychophysical assessments of image-sensor fused imagery. *Human Factors, 44,* 257-271.

Lemoine, M-P., Debernard, S., Crévits, I., & Millot, P. (1996). Cooperation between humans and machines : first results of an experiment with a multi-level cooperative organisation in air traffic control. Computer Supported Cooperative Work. *Journal of Collaborative Computing, 5,* 299-321.

Lorenz, B., Di Nocera, F., Röttger, S., & Parasuraman, R. (2002). Automated fault-management in a simulated space flight micro-world. *Aviation, Space, and Environmental Medicine, 73,* 886-897.

Malin, J., & Schreckenghost, D.L. (1992). Making intelligent systems team players: overview for designers (*NASA Techn. Mem. 104751*). Houston, TX: Johnston Space Center.

Meier, C. (1998). Datenfusionsverfahren für die automatische Erfassung des Rollverkehrs auf Flughäfen. Unpublished doctoral thesis. Technical University Braunschweig.

Metzger, U., & Parasuraman, R. (2001a). The role of the air traffic controller in future air traffic management: An empirical study of active control versus passive monitoring. *Human Factors, 43,* 519-528.

Metzger, U., & Parasuraman, R. (2001b). Conflict detection aids for air traffic controllers in free flight: effects of reliable and failure modes on performance and eye movements. *Proceedings of the 11th International Symposium on Aviation Psychology. Columbus,* OH: Ohio State University.

Moray, N., Inagaki, T. & Itoh, M. (2000). Adaptive automation, trust, and self-confidence in fault management of time-critical tasks. *Journal of Experimental Psychology: Applied, 6,* 44-58.

Norman, D.A. (1990). The problem with automation: inappropriate feedback and interaction, not 'over-automation'. *Philosophical Transactions of the Royal Society of London, B 327,* 585-593.

Pacaux-Lemoine, M-P., & Debernard, S. (2002). Common work space for human-machine cooperation in air traffic control. *Control Engineering Practice 10,* 571-576.

Parasuraman, R., Molloy, R., & Singh, I.L. (1993). Performance consequences of automation-induced 'complacency'. *The International Journal of Aviation Psychology, 3,* 1-23.

Parasuraman, R., & Riley, V.A. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors, 39,* 230-253.

Parasuraman, R., Sheridan, T.B., & Wickens, C.D. (2000). A model of types and levels of human interaction with automation. *IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans, 30,* 286-297.

Rasmussen, J. (1983). Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. *IEEE Transactions on Systems, Man, Cybernetics, 13,* 257-266.

Rovira, E., McGarry, K., & Parasuraman, R. (2002). Effects of unreliable automation on decision making in command and control. *Proceedings of the Human Factors and Ergonomics 46th Annual Meeting* (pp. 428-432). Santa Monica, CA: HFES.

Rovira, E., Zinni, M., & Parasuraman, R. (2002). Effects of information and decision automation on multi-task performance. *Proceedings of the Human Factors and Ergonomics 46th Annual Meeting* (pp. 327-331). Santa Monica, CA: HFES.

Sarter, N.B., & Schroeder, B.K. (2001). Supporting decision-making and action selection under time pressure and uncertainty: the case of in-flight icing. *Human Factors, 43,* 573-583.

Sarter, N.B., & Woods, D.D. (1995). How in the world did we ever get into that mode? Mode error and mode awareness in supervisory control. *Human Factors, 37,* 5-19.

Sarter, N.B., & Woods, D.D. (2000). Team play with a powerful and independent agent: A full-mission simulation study. *Human Factors, 42*, 390-402.

Sarter, N.B., Woods, D.D, & Billings, C.E. (1997). Automation surprises. In G. Salvendy (ed.), *Handbook of human factors and ergonomics*, 2nd. ed, (pp. 1926-1943). New York, NY: Wiley.

Sheridan, T.B. (1992). *Telerobotics, automation, and human supervisory control.* Cambridge, MA: MIT Press.

Sheridan, T.B. (2000). Function allocation: algorithm, alchemy or apostasy? *International Journal of Human-Computer Studies, 52*, 203-216.

Vanderhaegen, F., Crévits, I., Debernard, S., & Millot, P. (1994). Human-machine cooperation : toward an activity regulation assistance for different air traffic control levels. *International Journal on Human-Computer Interaction, 6*, 65-104.

Völckers, U. (1991). Application of planning aids for air traffic control: design principles. Solutions, results. In J.A. Wise, V.D. Hopkin, & M.L. Smith (eds.), *Automation and system issues in air traffic control*, (pp. 169-172). Berlin: NATO ASI Series F73.

Wickens, C.D. (2002). Situation awareness and workload in aviation. *Current Directions in Psychological Science, 11*, 128-133.

Wickens, C.D., & Hollands, J. (2000). *Engineering psychology and human performance* (3rd ed.). New York: Prentice Hall.

Wickens, C.D., Mavor, A., Parasuraman, R., & McGee, J. (1998). *The future of air traffic control: Human operators and automation.* Washington DC: National Academy.

Wiener, E.L. (1988). Cockpit automation. In E.L. Wiener & D.C. Nagel (eds.) *Human factors in aviation*, (pp. 433-461). San Diego: Academic Press.

Wiener, E.L. (1989). Human factors of advanced technology ('glass cockpit') transport aircraft. (*NASA Tech. Rep. 117528*). Moffet Field, CA: NASA Ames Research Center.

Wiener, E.L., & Curry, R.E. (1980). Flight-deck automation: Promises and problems. *Ergonomics, 23*, 995-1011.

Wiener, E.L., Kanki, B.G., & Helmreich, R.L. (1993). *Cockpit resource management.* San Diego, CA: Academic.

Winograd, T., & Woods, D.D. (1997). Challenges for human-centred design. In J. Flanagan, T. Huang, P. Jones, & S. Kasif (eds.), *Human-centred systems: Information, interactivity, and intelligence.* Washington, DC: National Science Foundation.

Woods, D.D. (1994). Automation: apparent simplicity, real complexity. In M. Mouloua, & R. Parasuraman (eds.), *Human performance in automated systems: Current research and trends* (pp. 1-7). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Woods, D.D., Johannesen, L.J., Cook, R.I., & Sarter, N.B. (1994). *Behind human error: Cognitive systems, computers and hindsight.* Dayton, OH: CSERIAC.

References

1 Human-Centred Automation: Research and Design Issues

Aircraft Accident Investigation Commission (1996). Aircraft accident investigation report 96-5, China Airlines, Airbus Industries A300B4-622R, B1816, Nagoya Airport, April 26, 1994, Ministry of Transport, Japan. Prepared for the WWW by Sogarne, H. & Ladkin, P., July 1996.

Bainbridge, L. (1983). Ironies of automation. Automatica, I 9, 755-779.

Bannon, L.J. (2001). Toward a social and societal ergonomics: a perspective from computersupported cooperative work. In M. McNeese, E. Salas, & M. Endsley (eds.), New trends in cooperative activities: understanding system dynamics in complex environments (pp. 9-21). Santa Monica, CA: Human Factors and Ergonomic Society.

Bennett, K.B., & Flach, J.M. (1992). Graphical displays: Implications for divided attention, focussed attention, and problem solving, Human Factors, 34, 513-533.

Billings, C.E. (1991). Human centred aircraft automation: A concept and guidelines (NASA Tech. Memorandum 102885). Moffet Field, CA: NASA Ames Research Center.

Billings, C.E. (1997). Aviation automation: the search for a human-centred approach. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Brudnicki, D.J., & Me Farland, A.L. (1997). User Request Evaluation Tool (URET) conflict probe performance and benefits assessments. Technical Report. McLean, VA: Mitre Cooperation.

Campion, J., Brander, G., & Koritsas, E. (1998). Establishing common ground and competence in team performance. Proceedings of the RTO Human Factors and Medicine Panel Symposium RTO-MP-004 Collaboration Crew Performance in Complex Operational Systems held in Edinburgh, UK, 20-22 April 1998, pp. 30 11-4.

Comstock, J.R., & Arnegard, R.J. (1992). The multi-attribute task battery for humanoperator workload and strategic behavior research. (NASA Tech Memorandum No. 104I74) Hampton, VA: NASA Langley Research Center.

Christoffersen, K., & Woods. D.D. (2002). How to make automated systems team players. In E. Salas (ed.), Advances in human performance and cognitive engineering research, val. 2. Amsterdam, The Netherlands: Elsevier.

Crocoll, W.M., & Coury, B.G. (1990). Status or recommendation: selecting the type of information for decision-aiding. Proceedings of the Human Factors and Ergonomics Society 34th Annual Meeting (pp. 1524-1528). Santa Monica, CA: HFES.

Debernard,S.,Cathelain,S.,Crevits,1.,&Poulain,T.(2002).AMANDAproject:Delegationoftasksintheairtrafficcontroldomain.InM.BlayFournarino,A.M.PinnaDery,K.Schmidt,&P.Zarate(eds.),Cooperativesystemsdesign(pp.173190).Amsterdam,theNetherlands:lOS.

Dekker,S.W.A.(2001).Thereinventionofhumanerror.HumanFactorsandAerospaceSafety,I,247265.

Endsley,M.R.(1995).Measurementofsituationawarenessindynamicsystems.HumanFactors,37,6584.

Endsley,M.R.,&Kaber,D.B.(1999).Levelofautomationeffectsonperformance,situationawarenessandworkloadinadynamiccontroltask.Ergonomics,42,462492.

Endsley,M.R..&Kiris,E.O.(1995).Theoutoftheloopperformanceproblemandlevelofcontrolinautomation.HumanFactors,37,281394.

Eurocontrol(1998).Operationalconceptdocument.Brussels,Belgium:Author.

Fitts,P.M.(1951).Engineeringpsychologyandequipmentdesign.InS.S.Stevens(ed.),Handbookofexpe

rimentalpsychology(pp.13011306).NewYork,NY:Wiley.

Grote,G.,Weik,S.,Wafler,T.,&Zi:ilch,M.(1995).Complementaryallocationoffunctionsinautomatedworksystems.InY.Anzai,K,Ogawa,&H.Mori(eds.),Symbiosisofhumanandartifact.Amsterdam,TheNetherlands:Elsevier.

Hecker,P.,&Suikat,R.(2000).Pilotenassistenzsysteme:EinBeitragzurErhi:ihungderFlugsicherheit.InZentrumflirVerkehrderTechnischenUniversitatBraunschweig(ed.),AutomatisierungsundAssistenzsystemeflirTransportmittel.Mi:iglichkeiten,Grenzen,Risiken.FortschrittBerichteVDI,Reihe12,Nr.431,(pp.132146).DUsseldorf:VOl.

Hoc,JM.(2001).Towardsacognitiveapproachtohumanmachinecooperationindynamicsituations.InternationalJournalofHumanComputerStudies,54,509540.

Hoc,J.M.,&Cartier,X.(2002).Roleofacommonframeofreferenceincognitivecooperation:Sharingtasksbetweenagentsinairtrafficcontrol.Cognition,Technology&Work,4,3747.

Hoc,J.M.,&Lemoine,M.P.(1998).Cognitiveevaluationofhumanhumanandhumanmachinecooperationmodesinairtrafficcontrol.InternationalJournalofAviationPsychology,8,132.

Hockey,G.R.J.,Wastell,D.G.,&Sauer,1.(1998).Effectsofsleepdeprivationanduserinterfaceoncomplexperformance:Amultilevelanalysisofcompensatorycontrol.HumanFactors,40,233253.

Hollnagel,E.(1999).Fromfunctionallocationtofunctioncongruence.InS.Dekker&E.Hollnagel(eds.).Copingwithcomputersinthecockpit,(pp.2953).Aldershot,UK:Ashgate.

Hollnagel,E.,&Bye,A.(2000).Principlesformodellingfunctionallocation.InternationalJournalofHumanComputerStudies,52,253265.

Hollnagel,E.,&Woods,D.O.(1983).Cognitivesystemsengineering:newwineinnewbottles.InternationalJournalofManMachineStudies,18,583600.

Inagaki,T.(1999).Situationadaptiveautonomy:tradingcontrolofauthorityinhumanmachinesystems.InM.W.Scerbo&M.Mouloua(eds.),Automationtechnologyandhumanperformance:currentresearchandtrend(pp.154158).Mahwah,NJ:Erlbaum.

Jentsch,F.,Barnett,J.,Bowers,C.A.,&Salas,E.(1999).Whoisflyingthisplaneanyway?Whatmishapstellusaboutcrewmemberroleassignmentandaircrewsituationawareness.HumanFactors,41,114.

Jordan,N.(1963).Allocationoffunctionsbetweenmanandmachinesinautomatedsystems.JournalofAppliedPsychology,47,161165.

Krebs, W.K., & Sinai, M.J. (2002). Psychophysical assessments of image-sensor fused imagery. Human Factors, 44, 257-271.

Lemoine, M-P., Debemard, S., Crevits, I., & Millot, P. (1996). Cooperation between humans and machines : first results of an experiment with a multi-level cooperative organisation in air traffic control. Computer Supported Cooperative Work. Journal of Collaborative Computing, 5,

299-321.

Lorenz, B., Di Nocera, F., Rottger, S., & Parasuraman, R. (2002). Automated faultmanagement in a simulated space flight micro-world. Aviation, Space, and Environmental Medicine, 73, 886-897.

Malin, J., & Schreckenghost, D.L. (1992). Making intelligent systems team players: overview for designers (NASA Techn. Mem. 104751). Houston, TX: Johnston Space Center.

Meier, C. (1998). Datenfusionsverfahren flir die automatische Erfassung des Rollverkehrs auf Flughafen. Unpublished doctoral thesis. Technical University Braunschweig.

Metzger, U., & Parasuraman, R. (2001a). The role of the air traffic controller in future air traffic management: An empirical study of active control versus passive monitoring. Human Factors, 43, 519-528.

Metzger, U., & Parasuraman, R. (2001b). Conflict detection aids for air traffic controllers in free flight: effects of reliable and failure modes on performance and eye movements. Proceedings of the 11th International Symposium on Aviation Psychology. Columbus, OH: Ohio State University.

Moray, N., Inagaki, T. & ltoh, M. (2000). Adaptive automation, trust, and self-confidence in fault management of time-critical tasks. Journal of Experimental Psychology: Applied, 6, 44-58.

Norman, D.A. (1990). The problem with automation: inappropriate feedback and interaction, not 'over-automation'. Philosophical Transactions of the Royal Society of London, B 327, 585-593.

Pacaux-Lemoine, M-P., & Debemard, S. (2002). Common work space for human-machine cooperation in air traffic control. Control Engineering Practice 10, 571-576.

Parasuraman, R., Molloy, R., & Singh, I.L. (1993). Performance consequences of automation-induced 'complacency'. The International Journal of Aviation Psychology, 3, 1-23.

Parasuraman, R., & Riley, V.A. (1997). Humans and automation: Use, misuse, disuse, abuse. Human Factors,

39, 230-253.

Parasuraman, R., Sheridan, T.B., & Wickens, C.D. (2000). A model of types and levels of human interaction with automation. IEEE Transactions on Systems, Man, and CyberneticsPart A: Systems and Humans, 30, 286-297.

Rasmussen, J. (1983). Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. IEEE Transactions on Systems, Man, Cybernetics, 13, 257-266.

Rovira, E., McGarry, K., & Parasuraman, R. (2002). Effects of unreliable automation on decision making in command and control. Proceedings of the Human Factors and Ergonomics 46th Annual Meeting (pp. 428-432). Santa Monica, CA: HFES.

Rovira, E., Zinni, M., & Parasuraman, R. (2002). Effects of information and decision automation on multi-task performance. Proceedings of the Human Factors and Ergonomics 46th Annual Meeting (pp. 327-331). Santa Monica, CA: HFES.

Sarter, N.B., & Schroeder, B.K. (2001). Supporting decision-making and action selection under time pressure and uncertainty: the case of in-flight icing. Human Factors, 43, 573-583.

Sarter, N.B., & Woods, D.D. (1995). How in the world did we ever get into that mode? Mode error and mode awareness in supervisory control. Human Factors, 37, 5-19.

Sarter, N.B., & Woods, D.O. (2000). Team play with a powerful and independent agent: A full-mission simulation study. Human Factors, 42, 390-402.

Sarter, N.B., Woods, D.D, & Billings, C.E. (1997). Automation surprises. In G. Salvendy (ed.), Handbook of human factors and ergonomics, 2nd. ed, (pp. 1926-1943). New York, NY: Wiley.

Sheridan, T.B. (1992). Telerobotics, automation, and human supervisory control. Cambridge. MA: MIT Press.

Sheridan, T.B. (2000). Function allocation: algorithm, alchemy or apostasy? International Journal of Human-Computer Studies, 52, 203-216.

Vanderhaegen, F., Crevits, 1., Debernard, S .• & Millot, P. (1994). Human-machine cooperation : toward an activity regulation assistance for different air tratlic control levels. International Journal on Human-Computer Interaction, 6, 65-104.

Volckers, U. (1991). Application of planning aids for air tratlic control: design principles. Solutions, results. In J.A. Wise, V.D. Hopkin, & M.L. Smith (eds.), Automation and system issues in air traffic control, (pp. 169-172). Berlin: NATO AS! Series F73.

Wickens, C.D. (2002). Situation awareness and workload in aviation. Current Directions in Psychological Science, II, 128-133.

Wickens, C.D .• & Hollands, 1. (2000). Engineering psychology and human performance (3rd ed.). New York: Prentice Hall.

Wickens, C. D., Mavor, A., Parasuraman, R., & McGee, J. (1998). The fitture of air traffic control: Human operators and automation. Washington DC: National Academy.

Wiener, E.L. (1988). Cockpit automation. In E.L. Wiener & D.C. Nagel (eds.) Human factors in aviation, (pp. 433-461). San Diego: Academic Press.

Wiener. E.L. (1989). Human factors of advanced technology ('glass cockpit') transport aircraft. (NASA Tech. Rep. II7528). Moffet Field, CA: NASA Ames Research Center.

Wiener, E.L., & Curry, R.E. (1980). Flight-deck automation: Promises and problems. Ergonomics, 23, 995-10 II.

Wiener, E.L., Kanki, B.G., & Helmreich, R.L. (1993). Cockpit resource management. San Diego, CA: Academic.

Winograd, T., & Woods, D.O. (1997). Challenges for human-centred design. In J. Flanagan, T. Huang, P. Jones, & S. Kasif (eds.), Human-centred systems: Information, interactivity, and intelligence. Washington, DC: National Science Foundation.

Woods, D.O. (1994). Automation: apparent simplicity, real complexity. In M. Mouloua, & R. Parasuraman (eds.), Human performance in automated systems: Current research and trends (pp. l-7). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Woods, D.O., Johannesen, L.J., Cook, R.I., & Sarter, N.B. (1994). Behind human error: Cognitive systems, computers and hindsight. Dayton, OH: CSERIAC.

Billings, C.E. (1991). Human-centered aircraft automation: a concept and guidelines. NASA Technical Memorandum, Ames Research Enter, Moffett Field, CA.

Dowell, J. & Long, J. (1998). Conception of the cognitive engineering design problem. Ergonomics, Vol. 41, No.2, 126-139.

Durso, F.T., Hackworth, C.A., Truitt, T.R., Crutchfield, J., Nikolic, D. & Manning, C.A. (1998). Situation Awareness as a Predictor of Performance for En Route Air Traffic Controllers. Air Traffic Control Quarterly, Vol. 6, No. I, 1-20.

Endsley,M.R.,(1988).SituationAwarenessGlobalAssessmentTechnique(SAGAT).In:ProceedingsoftheNationalAerospaceandElectronicsConference(NAECON),789795.

Endsley,M.R.(1989).Amethodologyfortheobjectivemeasurementofsituationawareness.AGARDConferenceProceedings:SituationAwarenessinAerospaceOperations.AGARDCP478,111119.

Endsley,M.R.&Kaber,D.B.(1999).Levelofautomationeffectsonperformance,situationawarenessandworkloadinadynamiccontroltask.Ergonomics,Vol.42,No.3,462492.

Endsley,M.R.&Jones,W.M.(2001).AModelofInterandIntrateamSituationalAwareness:ImplicationsforDesign,Training,andMeasurement.InM.McNeese,E.Salas&M.Endsley(eds.),NewTrendsinCooperativeActivities:UnderstandingSystemDynamicsinComplexEnvironments,pp.4667,SantaMonica,CA.:TheHumanFactorsandErgonomicsSociety.
EUROCONTROL(2001).TowardsCoope

rativeATS.TheCOOPATSConcept.FinalReport.

EUROCONTROL(2001).TowardsCooperativeATS.TheCOOPATSConcept.FinalReport.

Farley,T.C.,Hansman,R.J.,Endsley,M.R.,Amonlirdviman,K.&VigeantLanglois,L.(I998).TheEffectofSharedInformationonPilot/ControllerSituationAwarenessandReRouteNegotiation.InternationalAirTrafficManagementR&DSeminarATM98,Orlando,Fla.http://atmseminar98.eurocontrol.fr.

FlightInternational(2000).DataOverload.FlightInternational,713March,p.35.

Funabiki,K.,Tenoort,S.&Schick,F.(1999).TrafficInformationDisplayEnhancingPilotSituationAwareness:PARTI.PaperAIAA994023,AmericanInstituteofAeronauticsandAstronautics,ModellingandSimulationTechnologiesConference,PortlandUSA.

Hart,S.G.&Staveland,L.E.(1988).DevelopmentoftheNASATLX(TaskLoadIndex):ResultsofEmpiricalandTheoreticalResearch.InP.A.Hanock&N.Meshkati(eds.),HumanMentalWorkload,Amsterdam,TheNetherlands.

Hecker,P.&Suikat,R.(2000).Pilotenassistenzsysteme:EinBeitragzurErhohungderFlugsicherheit.In:VDIFortschrittBerichteReihe12,Nr.431,l.BraunschweigerSymposiumAutomatisierungsundAssistenzsystemeftirTransportmittel,132146.

Hoc,J.M.(2001).Towardsacognitiveapproachtohumanmachinecooperationindynamicsituations.Inter

nationalJournalofHumanComputer Studies,Vol.54,509540.

Hollnagel,E.,&Woods,D.D.(1983).CognitiveSystemsEngineering:newwineinnewbottles.Int.J.ofManMachineStudies,Vol.18,583600.

Kreifeldt,J.G.(1980).CockpitDisplayedTrafficInformationandDistributedManagementinAirTrafficControl.HumanFactors,Vol.22No.6,671691.

Kollmann,K.,Kupper,K.&Wetherly,J.(1997).CollaborativeDecisionMakinginAviationTransportation.

Lorenz,B.(2004).HumanCentredAutomation:ResearchandDesignIssues.ChapterIinthisvolume.

McGuinnes,B.(1995).SituationalAwarenessMeasurementinCockpitEvaluationTrials.AGARDCP575:AGARD/AMPSymposiumonSituationAwareness,Briissel.

Parasuraman,R.(1998).TrafficAlertandCollisionAvoidanceSystem.InWickens,C.D.,Mavor,A.S.,Parasuraman,R.&McGee,J.P.(eds.)TheFutureofAirTrafficControl:HumanOperatorsandAutomation,128134,Washington,D.C.:NationalAcademyPress.

Reichmuth,J.,Schick,F.,Adam,V.,Hobein,A.,Link,A.,Teegen,U.,&Tennort,S.(1998).PD/2FinalReport.EUROCONTROLPHAREDOC977013.HumanIMachineInterfacesforCooperativeFlightGuidance47

Reid,G.B.&Nygren,T.E.(1988).TheSubjectiveWorkloadAssessmentTechnique:AScalingProcedureforMeasuringMentalWorkload.InP.A.Hancock&N.Meshkati(eds.),HumanM

ental Workload, Amsterdam, The Netherlands.

Wickens, C., & Hollands, J. (2000). Engineering Psychology and Human Performance. Prentice Hall, New York (3rd ed). This page intentionally left blank

3 Pilot Assistant Systems for Increased Flight Safety

Adam,V.,Teegen,U.(1997).PD/2FinalReport.AnnexF:AirborneAspectsofPD/2,EUROCONTROL,DOC971013,1997.

Adam,V.,Ingle,G.,Rawlings,R.(1993).ExperimentalFlightManagementSystem,AGARDCP538,1993,Berlin.

Doehler,H.U.;Bollmeyer,D.(1997).'Simulationofimagingradarforobstacleavoidanceandenhancedvision'inEnhancedandSyntheticVision1997,J.G.Verly(ed.),SPIEVol.3088,1997,pp.6473.

Hecker,P.;Doehler,H.U.(1998).'EnhancedVisionSystems:ResultsofSimulationandOperationalTests'inEnhancedandSyntheticVision1998,J.G.Verly(ed.),SPIEVol.3364,1998.

Hecker,P.;Diihler,H.U.;Suikat,R.(1999A).'EnhancedVisionMeetsPilotAssistance',inEnhancedandSytheticVision1999,J.G.Verly(ed.),SPIEVol.3691,1999,Orlando,USA.

Hecker,P.(1999B).'AircrewAssistancebySophisticatedVisionSystems,ConceptsforIncreasedFlightSafety',InternationalWorkshopOnTechn.ElementsforAviationSafety,1999,Tokyo.

Helmke,H.,Hiippner,F.,Suikat,R.(1997).GenericArchitectureforaPilotAssistantSystem,ConferenceproceedingsofTheHumanElectronicCrew:TheRightStuff?,Kreuth,Germany,I997.

Korn,B.;Diihler,H.U.;Hecker,P.(1999).'MMWRadarDataProcessing

forEnhancedVision',EnhancedandSytheticVision1999,J.G.Verly(ed.),SPIEVol.3691,1999,Orlando,USA.

Onken,R.(1990).'KnowledgeBasedCockpitAssistantforIFROperations,in:KnowledgeBasedSystemsandApplicationsinGuidanceandControl',AGARDCP474,CGMSymposium,Madrid,1990,pp.14.114.9.

Rodloff,R.;Diihler,H.U.;Hecker,P.(1998).ImageDataFusionforEnhancedSitutationAwareness,RTOSC1Symposiumon:'TheApplicationofInformationTechnologiestoMissionSystems',1998,Monterey,USA.

Suikat,R.,Helmke,H.Hiippner,F.(1999).'PilotenunterstttitzungGatetoGatealsAntwortaufdiezuktinttigernAnforderungenimCockpit',DGLRJahrestagung,1999,Berlin.

4 Human Factors in the Design and Certification of a New Aircraft

AerospaceIndustriesAssociation/AircraftEuropeanContractorsManufacturersAssociationProjectReport(1998).PropulsionSystemMalfunctionplusInappropriateCrewResponse(PSM+ICR),VolumeI.

Amalberti,R.,Paries,J.,Valot,C.,Wibaux,F.(1998).Humanfactorsinaviation:Anintroductorycourse.InK.M.Goeters(ed.),Aviationpsychology:Ascienceandaprofession.Aldershot,UK:Ashgate.

Amalberti,R.&Wibaux,F.(2000).Advancedautomationglasscockpitcertification.InJ.A.Wise&V.D.Hopkin(eds.),HumanFactorsincertification.Mahwah,NJ:LawrenceErlbaum.

CAA(2000).PNPA25310,IssueI,HumanCenteredDesignRequirements,DatedApril2000,Gatwick,England.

Cooper,G.E.,&Harper,R.P.,Jr.(1969).Theuseofpilotratingsintheevaluationofaircrafthandlingqualities(NASATech.Rept.TND5I53).

Eurocontrol(200I).GuidelinesforEATMPProgrammesSafetyAssessment.Available:http://www.eurocontroI.intisafetyIdownloads/Gui_Saf_Assess/basicsofsafety/ilia_text.htm.

FAA(1987).FAAAdvisoryCircular25II,ElectronicDisplaysinTransportCategoryAirplanes.WashingtonDC:FAA.

FAA(1996).Humanfactorsstudyteamreportontheinterfacesbetweenflightcrewsandmodernflightdecksystems.WashingtonDC:FAA.

FAA(1998a).CodeofFederalRegulations(CFRI4),Parts159&60139,Draft13.Washington,DC:FAA.

FAA(1998b).FederalAviationRegulationsFAR25LargeAirplanes.Washington,DC:FAA.

FAA(1999a).FederalRegister,HFHWGJuly22,I999.Available:http://www.researchintegrations.com/hfhwg/fedregtaskingindex.htm.

FAA(1999b).GuidanceforReviewingHumanFactorsCertificationPlans.FAAPolicyStatementNumberANM992.Washington,DC:FAA.

FlightSafetyFoundation(January1997).Piloterror,weatherweremostfrequentinitialsourcesofcommercialjettransportapproachandlandingaccidents,19581995.FlightSafetyFoundationFlightSafetyDigest.Washington,DC:Author.

Hart,S.G.&Staveland,L.E.(1988).DevelopmentofNASATLX(TaskLoadIndex):Resultsofempiricalandtheoreticalresearch.InP.A.Hancock&N.Meshkati(eds.),Humanmentalworkload(pp.139183).Amsterdam:NorthHolland.

HumanFactorsHarmonisationWorkingGroup(200I).Interimreport.Available:www.researchintegrations.com/ht:hwg/index.htm.

InternationalStandardsOrganisation9241(19971998).Parts11,14,15,17,InternationalStandardErgonomicRequirementsforofficeworkwithvisualdisplayterminals(VDTs).

JAA(1998).JointAviationRequirementsJAR25LargeAirplanes.Hoofddorp,Netherlands:Author.

JAA (2001). Human Factors Aspects of Flight Deck Design Issue 2, JAA Interim Policy !NT/POL/25/14. Available: http://www.srg.caa.co.uk/documents/intpol.pdf.

JAA HF Steering Group (2001). Splasher Starting Point to Learn About Safety and Human Error Risks, Issue I, Sept. 200I. Available: http://www.hfstg.org.

Lyne, L. & Hansman, R.J. (200I). Recommended practices for human factors evaluation development process for advanced avionics. MIT International Center for Air Transportation Department of Aeronautics and Astronautics. Cambridge, MA.

NASA Ames Research Center (1986). NASA Task Load Index (TLX): Paper and Pencil Version. Moffett Field, CA: NASA Ames Research Center Aerospace Human Factors Research Division.

Parasuraman, R. & Hancock, P.A. (200 I). Adaptive control of mental workload. In Hancock, P.A. and Desmond, P.A. (eds.) Stress, workload, and fatigue (pp. 305-320). Mahwah, NJ: Lawrence Erlbaum Associates.

Paries, J. (2000). Some inadequacies of current human factors certification process of advanced aircraft technologies. In J. A. Wise & V. D. Hopkin (eds.), Human Factors in certification. Mahwah, NJ: Lawrence Erlbaum.

Sarter, N.B. & Woods, D.O. (2000). Team play with a powerful and independent agent: A full-mission simulation study. Human Factors, 42, 390-402.

Singer, G. & Dekker, S. (2001). The ergonomics of flight management systems: Fixing holes in the cockpit certification net. Applied Ergonomics, 32, 247-254.

5 Ability Requirements in Core Aviation Professions: Job Analyses of Airline Pilots and Air Traffic Controllers

Amelang,M.&Bartussek,D.(1981).DifferentiellePsychologieundPersonlichkeitsforschung.Stuttgart:Kohlhammer.

CAST.(1998).ConsequencesoffutureATMsystemsforairtrafficcontrollerSelectionandTraining.WPI:CurrentandFutureATMSystems.InECFPIVDGVII:AirTransportProject(ed.),AI97SC.2029.Brussels:EuropeanCommission.

Deuchert,I.(2002).Upgradingflightdataspecialists.InH.EiBfeldt,M.C.Heil&D.Broach(eds.),StaffingtheATMsystemtheselectionofairtrafficcontrollers(pp.139151).Aldershot:Ashgate.

EATCHIP.(1996).Guidelinesfordevelopingandimplementingteamresourcemanagement.InEurocontrol(ed.),HUMETI.STIO.JOOO_GUJOJ.Brussels:EUROCONTROL.

Ei/3feldt,H.(1997).AbilityrequirementsfordifferentATCpositions.InR.S.Jensen&L.Rakovan(eds.),ProceedingsoftheNinthInternationalSymposiumonAviationPsychology,Columbus,OhioUSA(Vol.I,pp.123128).Columbus:TheOhioStateUniversity.

Ei/3feldt,H.(1998).Theselectionofairtrafficcontrollers.InK.M.Goeters(ed.),AviationPsychology:AScienceandaProfession(pp.7380).Aldershot:Ashgate.

Eil3feldt,H.(1999).AbilityrequirementsforAirTrafficControllersinfutureATMsystems.InR.S.Jensen,B.Cox,J.D.Callister&R.Lavis(eds.),ProceedingsoftheTenthI

nternationalSymposiumonAviatio
nPsychology,Columbus,OhioUSA(V
ol.I,pp.592597).Columbus:TheOh
ioStateUniversity.

Ei/3feldt,H.,Deuchert,I.&Bierw
agen,T.(1999).Abilityrequireme
ntsforfutureATCsystemsasimulat
ionstudyusingresearchfacilitie
sofDFSDeutscheFlugsicherungGmb
H.InDLRForschungsbericht9915.H
amburg:DLR.

Eil3feldt,H.,Goeters,K.M.,Dami
tz,M.,Grasshoff,D.,Pecena,Y.,S
chwert,T.,Scholz,B.&Levin,A.(2
001).EignungsauswahlfiirdenFlu
gverkehrskontrolldienst.Entwic
klungsstandundKontrolledesVerf
ahrens.DLRIB31620010I.Hamburg,
DLR.

Eil3feldt,H.&Heintz,A.(2002).A
bilityrequirementsforDFScontro
llersCurrentandfuture.InH.Ei/3
feldt,M.C.Heil&D.Broach(eds.),
StaffingtheATMsystemtheselecti
onofairtrafficcontrollers(pp.1
324).Aldershot:Ashgate.

Eil3feldt,H.,Goeters,K.M.,Horm
ann,H.J.,Maschke,P.&Schiewe,A.
(1994).EffektivesArbeitenimTea
m:CrewResourceManagementTraini
ngfiirPilotenundFluglotsen.DLR
Mitteilung9409.Hamburg:DLR.

Fleishman.E.A.(1992).TheFleish
manJobAnalysisSurvey(FJAS).Pal
oAlto:ConsultingPsychologistsP
ress,Inc.

Fleishman,E.A.andHempel,W.E.(1
954).Changesinfactorstructureo
facomplexpsychomotortaskasafun
ctionofpractice.Psychometrika1
9,239252.

Fleishman,E.A.&Reilly,M.E.(199
2a).FleishmanJobAnalysisSurvey

(FJAS)Administrator'sGuide.PaloAlto:ConsultingPsychologistsPress,Inc.

Fleishman,E.A.&Reilly,M.E.(1992b).HandbookofHumanAbilities.Definitions,Measurements,andJobTaskRequirements.PaloAlto:ConsultingPsychologistsPress,Inc.AbilityRequirementsinCoreAviationProfessions119

Goeters,K.M.&Maschke,P.(1998).AnforderungsprotilbeiLinienflugzeugfiihrern1997.FlightcrewInfo,3198,1017.

Gopher,D.&Kahneman,D.(1971).IndividualdifferencesinattentionandthepredictionofflightcriteriaPerceptualandMotorSkills33,13351342.

Gubser,F.(1963).ApparativeUntersuchungsmittelinderPilotenauswahl.AviationPsychologyResearch,189192.

Guilford.J.P.&Lacey,J.I.(1947).Printedclassificationtests.Washington:DefenceDocumentationCenter.

Heintz,A.(1998).AnforderungsanalyseninderFlugverkehrskontrolle:EinVergleichverschiedenerArbeitspositionen.DLRFB9818.Hamburg:DLR.

Hormann,H.J.(1998).Selectionofcivilaviationpilots.In:Goeters,K.M.(ed.).AviationPsychology:Ascienceandaprofession.Aldershot:Ashgate.

Hormann,H.J.,Manzey,D.&Finell,G.(1989).TOMTestofmultipletaskperformance.DLRFB8960.Hamburg:DLR.

Kerns,K.(1991).DataLinkcommunicationbetweencontrollersandpilots:Areviewandsynthesisofthesimulationliterature.InternationalJournalofAviationPsychologyI,181204.

Manning,C.A.,&Broach,D.(1992).IdentifyingabilityrequirementsforoperatorsoffutureautomatedAirTrafficControlsystems.InOfficeofAviationMedicine(ed.),DOTJFAA!AM92126.Washington,D.C.:FAA.

Maschke,P.&Goeters,K.M.(1999).AnforderungenanFlugschlilerinderAbInitioAusbildungimVergleichzuaktivenLinientlugzeugftihrern.DLRFB9916.Hamburg:DLR.

Maschke,P.,Goeters,K.M.&Klamm,A.(2000).Jobrequirementsofairlinepilots:Resultsofajobanalysis.InLowe,A.R.&Hayward,B.J.(eds.).AviationResourceManagement(Vol.ll,17).Aldershot:Ashgate.

Pawlik,K.(1968).DimensionendesVerhaltens.Stuttgart:Huber.

Seifert,R.(1966).NeueGeratezurUntersuchungderPsychomotorik.Diagnostica12,616.

Wickens,C.D.,Mavor,A.S.,Parasuraman,R.&McGee,J.P.(1998).TheFutureofAirTrafficControl.Washington:NationalAcademyPress. This page intentionally left blank

6 Computer Assisted Testing (CAT) in Aviation Psychology

Aguinis,H.,Henle,C.A.&Beatyjr.,J.C.(2001).VirtualRealityTechnology:ANewToolforPersonnelSelection.In:InternationalJournalofSelectionandAssessment,Vol.9,Nos.1I2,pp.7083,BlackwellPublishers,Oxford.

Bartram,D.(1995).Newdevelopmentsincomputerbasedtesting:Thefuturetorpilotselectionprocedures.PaperpresentedtotheEighthsfnternationalSymposiumonAviationPsychology,Columbus,Ohio.

Beringer,J.(1993).EntwurfeinerAnwendersprachezurSteuerungpsychologischerReaktionszeitexperimente.EuropdischeHochschulschriften.Frankfurta.M.:Lang.

Bugbee,A.C.&Bernt,F.M.(1990).TestingByComputer:FindingsinSixYearsofUse19821988.JournalofResearchonComputinginEducation,Vol.23,No.I,pp.87100.

Drasgow,F.&OlsonBuchanan,J.B.(eds.)(1999).fnnovationsinComputerisedAssessment.LawrenceErlbaumAssociatesPublishers,Mahwah,NewJersey.

Goeters,K.M.&Rathje,H.(eds.)(1992).ComputergenerierteParallelTestsftirdieFahigkeitsmessunginderEignungsauswahlvonoperationellemLuftfahrtpersonal.DLRFB9229,Hamburg.

Goeters,K.M.&Maschke,P.(1998).AnforderungsprofilbeiLinienflugzeugftihrern1997.Flightcrewinfo,Heft3,1998.

Hagebock,J.(1994).ComputergestiitzteDiagnostikinderPsychoIogie.DissertationanderFreienUniversitatBerlin,HogrefeVerlagfiirPsychologie,Gottingen.

Huelmann,G.(1999).EntwicklungundEvaluationeinescomputergestiitztenTestverfahrenszurvisuellenWahrnehmungsgeschwindigkeit.Diplomarbeit,UniversitatHamburg.

Lorenz,B.,Rathje,H.,Goeters,K.M.,Finell,G.&Lamschus,D.(1996).Empiricalcomparisonoffullscaleselectionmethods(DLR)andcomputerassistedtesting(HAL).DLRFB9602,Hamburg.

Manzey,D.,Finell,G.&Albers,F.(2001).MultipleTaskCoordinationTest:EinneuesVerfahrenzurErfassungvonMehrfacharbeitsleistungenimRahmenpsychologischerAuswahluntersuchungenbeiFlugzeugfihrern.DLRFB200/05,Hamburg.

Mead,A.D.&Drasgow,F.(1993).Equivalenceofcomputerisedandpaperandpencilcognitiveabilitytests:Ametaanalysis.PsychologicalBulletin,Vol.114,pp.449458.

Mills,C.N.,Potenza,M.T.,Fremer,J.J.&Ward,C.(eds.)(2002).ComputerBasedTesting:BuildingtheFoundationforFutureAssessments.LawrenceErlbaumAssociatesPublishers,Mahwah,NewJersey.

Moe,K.C.&Johnson,M.F.(1988).ParticipantsReactionstoComputerisedTesting.JournalofEducationalComputingResearchVol.4,No.1,pp.7986.

Oubaid,V.,Adam,N.,Bolz,C.,Grasshoff,D.,Huelmann,G.,Schwert,T

.&Zierke,0.(2002).CAT4DieWeiterentwicklungdesSystemsCATzurcomputergestiltztenDurchfiihrungvonEignungsuntersuchungenbeimDLR.{ThedevelopmentofCAT4forcomputerisedaptitudetestingatDLR}DLRIB316200204,Koln,DLR.

Sands,W.A.,Waters,B.K.&McBride,J.R.(eds.)(1997).ComputerisedAdaptiveTestingFromInquirytoOperation.AmericanPsychologicalAssociation,Washington.

Urban,C.M.(1986).InequitiesinComputerEducationDuetoGender,Race,andSocioeconomicStatus.ExitProject,IndianaUniversity.

VanderLinden,W.&Glas,C.A.W.(eds.)(2000).ComputerisedAdaptiveTesting·TheoryandPractice.KluwerAcademicPublishers,Dordrecht.

Wainer,H.(ed.)(2000).ComputerisedAdaptiveTesting:APrimer.LawrenceErlbaumAssociates,Publishers,Mahwah,NewJersey.

Carretta, T.R., & Ree, M.J. (1995). Air Force Officer Qualifying Test validity for predicting pilot training performance. Journal of Business and Psychology, 9, 379-388.

Carretta, T.R., & Siem, F.M. (1999). Determinants of enlisted air traffic controller success. Aviation, Space, and Environmental Medicine, 70, 910-918.

Damitz, M., EiBfeldt, H., Grasshoff, D., Lorenz, B., Pecena, Y., & Schwert T., (2000). Validierung des DLR-Auswahlverfahrens fur Nachwuchsjluglotsen der DFS Deutsche Flugsicherung GmbH: Ergebnisse des Projektes Qualitdtssicherung [Validation of the DLR Selection Program for DFS Deutsche Flugsicherung GmbH Ab-lnitio Air Traffic Controllers: Results of the Project Quality Assurance] (DLR-Forschungsbericht 200045). Hamburg, Germany: DLR.

EATCHIP (1997). lnfonnation on available and emerging selection tests and methods for ab initio trainee controllers (HUM.ETI.ST04.10000-REP-01). Brussels, Belgium: EUROCONTROL.

EATMP (2000). Update of information on selection tools and methods for ab initio trainee controllers (HRS!MSP-002-REP-01). Brussels, Belgium: EUROCONTROL.

EiBfeldt, H., Deuchert, I., & Bierwagen, T. (1999). Ability requirements for future ATM systems comprising datalink: A simulation study using an EATCHJP Ill based platform (DLR-Forschungsbericht 1999-15). Hamburg, Germany: DLR.

Hough, L.M., & Oswald, F.L. (2000). Personnel selection: Looking toward the future remembering the past. Annual Review of Psychology, 51, 631-664.

Jensen, A.R. (1994). What is a good g? Intelligence, 18, 231-258.

Lawley, D.N. (1943). A note on Karl Pearson's selection formulae. Proceedings of the Royal Society of Edingburgh, 62, (section A, pt. 1), 28-30.

Olea, M.M., & Ree, M.J. (1994). Predicting pilot and navigator criteria: not much more than g. Journal of Applied Psychology, 79, 845-851.

Ree, M.J., & Carretta, T.R. (1996). Central role of g in military pilot selection. The International Journal of Aviation Psychology, 6, 111-123.

Ree, M.J., & Earles, J.A. (1991). Predicting training success: Not much more than g. Personnel Psychology, 44, 321-332.

Spearman, C. (1904). 'General intelligence', objectively determined and measured. American Journal of Psychology, I 5, 201-293.

Thurstone, L.L. (1938). Primary mental abilities. Psychometric Monographs No. 1.

Burke,E.F.(1993).PilotselectioninNATO:Anoverview.InR.S.Jensen&D.Neumeister(eds.),ProceedingsoftheSeventhInternationalSymposiumonAviationPsychology(pp.373378).Columbus:TheOhioStateUniversity.

Cattell,R.B.,Eber,H.W.,&Tatsouka,M.M.(1970).HandbookoftheSixteenPersonalityFactorQuestionnaire:Champaign,IL:InstituteforPersonalityandAbilityTesting.

Chidester,T.R.,Kanki,B.G.,Foushee,H.C.Dickinson,C.,&Bowles,S.(1990).Personalityfactorsinflightoperations:Leadercharacteristicsandcrewperformanceinafullmissionairtransportsimulation(NASATM102259).MoffettField,CA:NASAAmesResearchCenter.

Chidester,T.R.,Helmreich,R.L.,Gregorich,S.E.,&Geis,C.E.(1991).Pilotpersonalityandcrewcoordination:Implicationsfortrainingandselection.TheInternationalJournalofAviationPsychology,I,2544.

Cooper,G.E.,White,M.D.,&Lauber,J.K.(eds.)(1979).Resourcemanagementontheflightdeck(NASAConferencePublicationNo.2120;NTISNo.NS022083).MoffettField,CA:NASAAmesResearchCenter.

Costa,P.T.&McCrae,R.R.(1992).Normalpersonalityassessmentinclinicalpractice.TheNEOPersonalityInventory.PsychologicalAssessment,4,513.

EiBfeldt,H.(2002).Costsavings:Theuseofbiodatatoimproveselectionefficiency.Paperpresentedat

the25thEAAPConforence.Warsaw,Poland.

Flanagan,J.C.(1954).Thecriticalincidenttechnique.PsychologicalBulletin,51,327358.

Goeters,K.M.,Timmermann,B.&Maschke,P.(1993).TheconstructionofPersonalityquestionnairesforselectionofaviationpersonnel.TheInternationalJournalofAviationPsychology,3,123141.

Helmreich,R.L.(1984).Cockpitmanagementattitudes.HumanFactors,26,583589.

Helmreich,R.L.&Wilhelm,J.A.(1991).OutcomesofCrewResourceManagementtraining.TheInternationalJournalofAviationPsychology,I,287300.PersonalityEvaluationofApplicantsinAviation151

Hormann,H.J.&Maschke,P.(1996).Ontherelationbetweenpersonalityandjobperformanceofairlinepilots.TheInternationalJournalofAviationPsychology,6,171178.

Hunter,D.R.&Burke,E.F.(1994).Predictingaircraftpilottrainingsuccess:Ametaanalysisofpublishedresearch.TheInternationalJournalofAviationPsychology,4,297313.

Jackson,D.N.(1974).ManualofthePersonalityResearchForm(3rded.).PortHuron,MI:SigmaAssessmentSystems.

King,M.A.E.&MeGlohn,S.E.(1997).FemaleUnitedStatesairforcepilotpersonality:Thenewrightstuff.MilitaryMedicine,162,695697.

LathamG.P.&Saari,L.M.(1984).Dopeopledowhattheysay?Furtherstu

diesonthesituationalinterview.JournalofAppliedPsychology,69,569573.

Maschke,P.(1987).TemperamentStructureScales(TSS)(Tech.Rep.NoESATT1069).Oberpfaffenhofen,Germany:EuropeanSpaceAgency.

Maschke,P.,Goeters,K.M.&Klamm(2000).Jobrequirementsofairlinepilots:Resultsofajobanalysis.InLowe,A.R.&Hayward,B.J.(ed.),AviationResourceManagement(Vol.JJ,17).Aldershot:Ashgate.

Maschke,P.&Goeters,K.M.(2000).Abinitioflighttrainingandairlinepilotsperformance:Differencesinjobrequirements.PaperpresentedattheFifthAustralianAviationPsychologySymposium.Sydney,Australia.

O'Connor,P.,Hoermann,H.J.,Flin,R.,Lodge,M.&Goeters,K.M.(2002).DevelopingamethodforevaluatingCRMskills:AEuropeanperspective.InternationalJournalofAviationPsychology,12(3).

Reilly,R.R.&Chao,G.T.(1982).Validityandfairnessofsomealternativeemployeeselectionprocedures.PersonnelPsychology,35,162.

Roast,M.,Muir,H.&Harris,J.(2000).Apersonalitytestforaircrewselection:Goatsorsheep?.InLowe,A.R.&Hayward,B.J.(ed.),AviationResourceManagement(Vol.Jl,3341).Aldershot:Ashgate.

Shinar,Y.(1995).Personalityasthekeyfactorinthecompetenceofapilot.In:R.S.Jensen&L.A.Rakovan(ed.),Proceedingsofthe8thInternationalSymposiumonAviationPsychology(pp.11371141).Columbus:TheOhioStateUniversity.

Stahlberg,G.&Hoermann,H.J.(1993).InternationalapplicationoftheDLRtestsystem:ValidationofthepilotselectionforIBERIA.DLRResearchRep.NoDLRFB9342.Hamburg:DLR.

Stokes,A.F.&Bohan,M.(1995).Academicproficiency,anxiety,andinformationprocessingvariablesaspredictorsofsuccessinuniversityflighttraining.Proceedingsofthe8thInternationalSymposiumonAviationPsychology(pp.11071112).Columbus:TheOhioStateUniversity.

Wiesner,W.&Cronshow,S.(1988).Ametaanalyticinvestigationoftheimpactofinterviewformatanddegreeofstructureonthevalidityoftheemploymentinterview.JournalofOccupationalPsychology,61,275290. This page intentionally left blank

Boyle,S.,Fullerton,J.,&Wood,R.(1995).Doassessment/developmentcentresuseoptimumevaluationprocedures?AsurveyofpracticeinUKorganisations.InternationalJournalofSelectionandAssessment,3,132140.

Bycio,P.,Hahn,J.,&Alvares,K.M.(1987).Situationalspecifityinassessmentcenterratings:Aconfirmatoryfactoranalysis.JournalofAppliedPsychology,72,463474.

Campbell,D.T.&Fiske,D.W.(1959).Convergentanddiscriminantvaliditationbythemultitraitmultimethodmatrix.PsychologicalBulletin,56,81105.

Cronbach,L.J.&Meehl,P.E.(1955).Constructvalidityinpsychologicaltests.PsychologicalBulletin,52,281302.

Cronbach,L.J.(1990).Essentialsofpsychologicaltesting.Row:Harper.

Damitz,M.•Eil3feldt,H.,Grasshoff,D.,Lorenz,B.,Pecena,Y.,&Schwert,T.(2000).ValidierungdesDLRAuswahlverfahrensflirNachwuchst1uglotsenderDFSDeutscheFlugsicherungGmbH:ErgebnissedesProjektsQualitatssicherung.DRLForschungsbericht200045(ValidationoftheDLRSelectionProgramforDeutscheFlugsicherungGmbHAbInitioAirTrafficControllers:ResultsoftheProjectQualityAssurance.DLRresearchreport200045).Koln:DeutschesZentrumftirLuftundRaumfahrte.V.(DLR).

Damitz,M.,Manzey,D.,Kleinmann,

M.,&Severin,K.(2003).Assessmentcenterforpilotselection:Constructandcriterionvalidityandtheimpactofassessortype.AppliedPsychology:AnInternationalReview,52,193212.

Dunbar,S.B.&Linn,R.L.(1991).Rangerestrictionadjustmentsinthepredictionofmilitaryjobperformance.InA.K.Wigdor&B.F.Green(eds.),Performanceassessmentfortheworkplace,Vol.II.Washington,DC:NationalAcademyPress.

Fleenor,J.W.(1996).Constructsanddevelopmentalassessmentcenters:Furthertroublingempiricalfindings.JournalofBusinessandPsychology,10,319335.

Gaugler,B.B.,Rosenthal,D.B.,Thornton,G.C.,&Bentson,C.(1987).Metaanalysisofassessmentcentervalidity.JournalofAppliedPsychology,72,618.

Hotl,S.&Schuler,H.(2001).Theconceptualbasisofassessmentcentreratings.InternationalJournalofSelectionandAssessment,9,114123.

Hoft,S.(2002).2100NachwuchstlugzeugftihrerBewerberimAssessmentCenterdesDLR:ZeitlicheVerlaufsanalysenzuausgewahltenKonstruktvaliditatsindikatorenimEinsatzzeitraumMarz1999bisAugust2001.DLRForschungsbericht200215(2,100participantsintheassessmentcenterofDLRfortheselectionofabinitiopilottrainees:TemporaltrendanalysisofselectedconstructvalidityindicatorsfortheassessmentperiodfromMarch1999toAugust2001.DLRresearchreport200215).Koln:DeutschesZentrumftirLu

:ftundRaumfahrte.V.(DLR).

Hormann,H.J.&Maschke,P.(1996).Ontherelationshipbetweenpersonalityandjobperformanceofairlinepilots.InternationalJournalofAviationPsychology,6,171178.

Krause,D.&Gebert,D.(inpress).Acomparionofassessmentcenterpracticesinorganizationsin GermanspeakingregionsandtheUnitedStates.InternationalJournalofSelectionandAssessment.

Lord,F.M.&Novick,M.R.(1968).Statisticaltheoriesofmentaltestscores.Reading,MA:AddisonWesley.

Messick,S.(1989).Validity.InR.L.Linn(ed.),EducationalMeasurement(3ed.,pp.13103).NewYork:Macmillan.

Pecena,Y.(2000).AssessmentCenterzurAuswahlvonFlugzeugftihrern.DLRForschungsbericht200027(Assessmentcenterforpilotselection.DLRresearchreport200027).Koln:DeutschesZentrumftirLuftundRaumfahrte.V.(DLR).

Pecena,Y.(2002).Behaviourorientedassessmentofinterpersonalskillsin ATCOselection.InH.EiBfeldt,M.C.Heil,&D.Broach(eds.),StaffingtheATMSystem.Theselectionofairtrafficcontrollers(pp.97105).Aldershot:Ashgate.

Pecena,Y.(2003).ValidierungdesDLRAssessmentCenters'VerDi'ftirdieAuswahlvonNachwuchstluglotsenderDFSDeutscheFlugsicherungGmbH.DLRForschungsbericht200313(ValidationoftheDLRassessmentcentercalledVerDiforDFSDeutscheFlugsicherungGmbHAbInitioAirTrafficControllers).

Ryan,A.M.,Baron,H.,&Page,R.(1999).Aninternationallookatselectionpractices:Nationandcultureasexplanationsforvariabilityinpractice.PersonnelPsychology,52,359391.

Sackett,P.R.&Dreher,G.F.(1982).Constructsandassessmentcenterdimensions:Sometroublingempiricalfindings.JournalofAppliedPsychology,67,401410.

Schmidt,F.L.&Hunter,J.E.(1998).Thevalidityandutilityofselectionmethodsinpersonnelpsychology:Practicalandtheoreticalimplicationsof85yearsofresearchfindings.PsychologicalBulletin,124,262274.

Shrout,P.E.&Fleiss,J.L.(1979).IntraclassCorrelations:UsesinAssessingRaterReliability.PsychologicalBulletin,86,420428.

Spychalski,A.C.,Quinones,M.A.,Gaugler,B.B.,&Pohley,K.(1997).AsurveyofassessmentcenterpracticesinorganizationsintheUnitedStates.PersonnelPsychology,50,7190.

Stelling,D.(1999).TeamarbeitinMenschMaschineSystemen(Teamworkinmanmachinesystems).Gottingen:Hogrefe.

Taskforceonassessmentcenterguidelines(2000).Guidelinesandethicalconsiderationsforassessmentcenteroperations.PublicPersonnelManagement,29,315329.

Thornton,G.C.(1992).Assessmentcentersinhumanresourcemanageme

nt.Reading,MA:AddisonWesley.

Thornton,G.C.&Byham,W.C.(1982).Assessmentcentersandmanagerialperformance.NewYork:AcademicPress.

Turnage,J.J.&Muchinsky,P.M.(1982).Transsituationalvariabilityinhumanperformancewithinassessmentcenters.OrganizationalBehaviourandHumanPerformance,30,174200.

Wernimont,P.&Campbell,J.P.(1968).Signs,samples,andcriteria.JournalofAppliedPsychology,52,372376.

Ackerman,P.L.(1992).Predictingindividualdifferencesincomplexskillacquisition:Dynamicsofabilitydeterminants.JournalofAppliedPsychology,77,598614.

Ackerman,P.L.,Kanfer,R.,&Goff,M.(1995).Cognitiveandnoncognitivedeterminantsandconsequencesofcomplexskillacquisition.JournalofExperimentalPsychologyApplied,I,270304.

Ackerman,P.L.&Schneider,W.(1985).IndividualDifferencesinAutomaticandControlledInformationProcessing.In:R.F.Dillon(ed.),IndividualDifferencesinCognition.AcademicPress.

Alava,M.J.&Alvarez,J.(1999).CASATCO's'ComputerisedAssessmentSystemfortheselectionofAirTrafficControllers.In:EUROCONTROL(ed.),ProceedingsoftheFirstEUROCONTROLSelectionSeminar'CurrentandrequiredfutureselectionworkandmethodsintheECACarea'(pp.146154),HUMETI.ST04.1000REP02.Brussels:EUROCONTROL.

Brehmer,B.(1993).PrestationvidurvaletochutbildningsresultatIflygledarutbildning.MRUReportNo.7.Norrkoping:Luftfartsverket.

Brehmer,B.(1994).Aspectsofairtrafficcontrolwork.Aninitialanalysis.InSwedish(translationbyEUROCONTROL),Recruitment,selectionandtrainingofairtrafficcontrollerstudents(Vol.8).Norrkoping:Luftfartsverket.

Broach,D.(1999).ApreliminaryAnalysisofAirTrafficControlSpeci

alistJobKnowledge,Skill,andAbilityRequirementsAssociatedwithSelectedFreeFlightPhaselTechnologies.In:PaperpresentedfirstInternationalconferenceonATCselection.OklahomaCity:FAA.

Broach,D.(2002).AirTrafficControllerabilityrequirementsintheU.S.NationalAirspaceSystem.In:H.Eißfeldt,D.Broach,&M.Heil,(eds.),StaffingtheATMSystemTheSelectionofAirTrafficControllers.Aldershot:Ashgate.

CASTConsortium(1999a).WP2:FutureATCOdescription.(NLRTR98496).Amsterdam:NLR.

CASTConsortium(1999b).WP3:FutureATCOselectionandtraining.VolumeIIFutureATCOselection.(NLRTR99315VOL2).Amsterdam:NLR.

CASTConsortium(1999c).ConsequencesoffutureATMsystemsforairtrafficcontrollerSelectionandTraining:FinalReport.(NLRTR99369).Amsterdam:NLR.

Cox,M.(1994).TaskAnalysisofselectedoperatingpositionswithinUKAirTrafficControl.MainReport.In:RoyalAirForce(ed.),JAMReportNo.749.RAF.

Dover,S.(1999).AbilitiesandAptitudesRequiredofATCOCandidatesandActiveATCOs:CrossNationsandCulturesFindings.In:EUROCONTROL(ed.),ProceedingsoftheFirstEUROCONTROLSelectionSeminar'CurrentandrequiredfutureselectionworkandmethodsintheECACarea'(pp.5171),HUMETI.ST04.1000REP02.Brussels:EUROCONTROL.

Eißfeldt,H.(1988).BeurteilungsrelevanteLeistungskriterienimRahmenderpraktischenAusbildungz

umgehobenenFlugverkehrskontrolldienstEineUntersuchunganhandderCriticalIncidentTechnique.DLRIB3168807.

EiBfeldt,H.(1998).Theselectionofairtrafficcontrollers.In:K.M.Goeters(ed.),AviationPsychology:AScienceandaProfession(pp.7380).Aldershot:Ashgate.

EiBfeldt,H.,Deuchert,I.&Bierwagen,T.(1999).AbilityrequirementsforfutureATCsystemsasimulationstudyusingresearchfacilitiesofDFSDeutscheFlugsicherungGmbH.DLRForschungsbericht9915.Hamburg:DLR.

EiBfeldt,H.&Heintz,A.(2002).AbilityrequirementsforDFScontrollersCurrentandfuture.In:H.EiBfeldt,M.C.Heil&D.Broach(eds.),StaffingtheATMsystem.Theselectionofairtrafficcontrollers.Aldershot:Ashgate.

Endsley,M.R.(1999).Situationawarenessinaviationsystems.In:D.J.Garland,J.A.Wise,&V.D.Hopkin,(eds.),HandbookofAviationHumanFactors(pp.257276).Mahwah:LawrenceErlbaum.

EUROCONTROLHumanResourcesTeam(1996).Modelfortaskandjobdescriptionsofairtrafficcontrollers.HUM.ETI.STOI./000REP01.Brussels:EUROCONTROL.

EUROCONTROLHumanResourcesTeam(1997).InformationonAvailableandEmergingSelectionTestsandMethodsforAbinitioTraineeControllers,HUMETI.ST04./000REPOl.Brussels:EUROCONTROL.

EUROCONTROLHumanResourcesTeam(1998).SelectionTests,InterviewsandAssessmentCentresforAbinitioTraineeControllers:TechnicalSupplement,HRS/MSP002GU/0302.Brussels:EUROCONTROL.

EUROCONTROLHumanResourcesTeam(1999).ProceedingsoftheFirstEUROCONTROLSelectionSeminarCurrentandRequiredFutureSelectionWorkandMethodsintheECACArea,HUM.ETI.ST04./000REP02.Brussels:EUROCONTROL.

EUROCONTROLHumanResourcesTeam(2000).UpdateofInformationonSelectionToolsandMethodsforabinitioTraineeControllers,HRS/MSP002REP01.Brussels:EUROCONTROL.

EUROCONTROLHumanResourcesTeam(200la).GuidelinesforSelectionProceduresandTestsforAbinitioTraineeControllers(Revised),HRS/MSP002GU!0I.Brussels:EUROCONTROL.

EUROCONTROLHumanResourcesTeam(200lb).CharacteristicsofRecruitmentandPreselectionofAbinitioTraineeControllers(Revised),HRS/MSP002GUI02.Brussels:EUROCONTROL.

EUROCONTROLHumanResourcesTeam(2002).SelectionTests,InterviewsandAssessmentCentresforAbinitioTraineeControllers:GuidelinesforImplementation(Revised),HRS/MSP002GU/030I.Brussels:EUROCONTROL.

EUROCONTROLHumanResourcesTeam(2004).ProceedingsoftheSecondEUROCONTROLSelectionSeminar(inpress).Brussels:EUROCONTROL.

Haglund,R.,Backman,B.&Brehmer,B.(1994).Progressreport,phase2

:PresentationofcurrentactivitieswithintheANSDepartmentconcerningselectionofAirTrafficControllerstudents,andtrainingofteachersandinstructors.MRUReportNo.II.Norrkoping:Luftfartsverket.

Heintz,A.(1998).AnforderungsanalysenderFlugverkehrskontrolle:EinVergleichverschiedenerArbeitspositionen.In:DLRFB9818.Hamburg:DLR.

Herriot,P.&Anderson,N.(1997).SelectingforChange:HowwillPersonnelandSelectionPsychologySurvive?In:N.Anderson,&P.Herriot,(eds.),InternationalHandbookofSelectionandAssessment(pp.134).Chichester:Wiley.

HLG.(2000).SingleEuropeanSky,DraftReportoftheHighLevelGroup.

Hunter,J.&Schmidt,F.(1990).Methodsofmetaanalysis:Correctingerrorandbiasinresearchfindings.BeverlyHillsCA:Sage.

Landon,T.E.(1991).JobperformancefortheEnRouteATCS:AreviewwithapplicationsforATCSselection.PapersubmittedtoMinnesotaAirTrafficControllerTrainingCenter.

Manning,C.A.,&Broach,D.(1992).IdentifyingabilityrequirementsforoperatorsoffutureautomatedAirTrafficControlsystems.In:OfficeofAviationMedicine(ed.),DOT/FAA/AM92126.Washington,D.C.:FAA.PanEuropeanSelectionTestBatteryforAirTrafficControlApplicants201

NATO.(2000).ReportfromtheNordicANSSubGroupforRecruitmentandSelection,IISeptember2000,AnInternalReport,Copenhagen:NATO.

Nickels,B.J.,Bobko,P.,Blair,M.D.,Sands,W.A.,Tartak,E.L.(1995).SeparationandControlHiringAssessment(SACHA)FinalJobAnalysisReport.MD:Bethesda.

Nyfield,G.(1991).AutomationIssuesfortheSelectionofControllers.In:J.A.Wise,V.D.Hopkin&M.L.Smith(eds.),AutomationandSystemIssuesinAirTrafficControl(Vol.NATOASISeriesF,VolF73,pp.453460).Berlin:Springer.

Pearn,M.A.&Kandola,R.S.(1983).JobAnalysisofAirTrafficControllers.Esher,Surrey:SHL.

Peeters,R.(2000).RecruitmentProceduresforApplicant'Abinitio'Controller,AThesisworkpresentedattheoccasionofBELGOCONTROLATSExpertThesisExamination,November2000,Herent:BELGOCONTROL.

Schmidt,F.&Hunter,J.(1977).Developmentofageneralsolutiontotheproblemofvaliditygeneralization.JournalofAppliedPsychology,62(5),529540.

Schmidt,F.,Law,K.,Hunter,J.,Rothstein,H.,Pearlman,K.&McDaniel,M.(1993).Refinementsinvaliditygeneralizationmethods:implicationsforthesituationalspecificityhypothesis.JournalofAppliedPsychology,78(1),312.

Seamster,T.L.,Redding,R.E.,Cannon,J.R.&Ryder,J.M.(1993).Cognitivetaskanalysisofexpertiseinairtrafficcontrol.SpecialIssue:Airtrafficcontrolhumanfactors.InternationalJournalofAviationPsychology,3,257283.

Siem,F.M.&Carretta,T.R.(1998).DeterminantsofenlistedAirTraff

icControllersuccess.In:AirForceResearchLaboratory(ed.),ARLHEAZTR19980079.

Whitfield,D.,&Stammers,R.B.(1978).Theairtrafficcontroller.In:W.T.Singleton(ed.),Theanalysisofpracticalskills.Vol.1:Thestudyofrealskills.Lancaster,U.K.MTPPress. This page intentionally left blank

11 Cost-Benefit Analysis of Pilot Selection: The Economic Value of Psychological Testing

Goeters,K.M.,ed.(1998).AviationPsychology:Ascienceandaprofession.Aldershot(UK):Ashgate,pp.l03112.

Hormann,H.J.&Maschke,P.(1987).Avaliditystudyofaselectionprocedureforstudentairlinepilots.DFVLRFB8734(GermanwithEnglishabstract).

12 Cost Savings: The Use of Biodata to Improve Selection Efficiency in Aviation

Carlson,K.D.,Scullen,S.E.,Schmidt,F.L.,Rothstein,H.&Erwin,F.(1999).Generizablebiograhicaldatavaliditycanbeachievedwithoutmultiorganizationaldevelopmentandkeying.PersonnelPsychology,52,731756.

Damitz,M.,EiBfeldt,H.,Grasshoff,D.,Lorenz,B.,Pecena,Y.&Schwert,T.(2000).ValidierungdesDLRAuswahlverfahrensfUrNachwuchsfluglotsenderDFSDeutscheFlugsicherungGmbH:ErgebnissedesProjektesQualitatssicherung.DLRFB200045.Hamburg:DLR.

Dean,M.,Russell,C.J.,Farmer,W.(2002).Noncognitivepredictorsofairtrafficcontrollerperformance.InH.EiBfeldt,M.C.Heil&D.Broach(eds.),StaffingtheATMSystemTheselectionofairtrafficcontrollers(pp.5972).Aldershot:Ashgate.

EiBfeldt,H.(1999).TheUseofBiographicalDatainthePreSelectionofabinitioATCApplicants.InEUROCONTROL(ed.),ProceedingsoftheFirstEUROCONTROLSelectionSeminar'CurrentandRequiredFutureSelectionWorkandMethodsintheECACArea'HUM.ETI.ST04.1000REP02(pp.2334).Brussels:EUROCONTROL.

EiBfeldt,H.&Deuchert,I.(2002).TheSelectionSysteminuseinGermany.InH.EiBfeldt,M.C.Heil&D.Broach(eds.),StaffingtheATMsystemtheselectionofairtrafficcontrollers(pp.121130).Aldershot:Ashgate.

Eil3feldt,H.,Goeters,K.M.,Damitz,M.,Grasshoff,D.,Lorenz,B.,Pecena,Y.,Schwert,T.,Scholz,B.&

Hinemann,E.(1999).EignungsauswahlfUrdenFlugverkehrskontrolldienst.DLRIB316990I.Hamburg:DLR.

Eil3feldt,H.,Goeters,K.M.,Damitz,M.,Grasshoff,D.,Pecena,Y.,Schwert,T.&Scholz,B.(2000).EignungsauswahlfUrdenFlugverkehrskontrolldienst.DLRIB3I6000I.Hamburg:DLR.

Goeters,K.M.,Maschke,P.&EiBfeldt,H.(200I).OntheCostBenefitofpsychologicalselectionofaviationpersonnel.Paperpresentedatthesymposium'HumanIssuesinAviationSystems(HJAS)',Toulouse,2628September2001.

Muchinsky,P.M.(1986).Personnelselectionmethods.InC.L.Cooper&I.Robertson(eds.),InternationalReviewofIndustrialandOrganizationalPsychology.Chichester:Wiley.

Reilly,R.R.&Chao,G.T.(1982).Validityandfairnessofsomealternativeemployeeselectionprocedures.PersonnelPsychology,35,162.

Schmidt,F.L.&Hunter,J.E.(1998).Thevalidityandutilityofselectionmethodsinpersonnelpsychology:Practicalandtheoreticalimplicationsof85yearsofresearchfindings.PsychologicalBulletin,124,262274. This page intentionally left blank

13 The Current Status of CRM Training and its Regulation in Europe

CAASafetyRegulationGroup(2003).CAP737CrewResourceManagement(CRM)Training.GuidanceforFlightCrew.CRMInstructors(CRMis)andCRMInstructorExaminers(CRMIEs).

Helmreich.R.L.,Merritt,A.C.,&Wilhelm,J.A.(1999).TheevolutionofCrewResourceManagementtrainingincommercialaviation.InternationalJournalofAviationPsychology,9(I),1932.

Klampfer,B.,Flin,R.,Helmreich,R.L.,Hausler,R.,Sexton,B.,Fletcher,G.,Field,P.,Staender,S.,Lauche,P.,Dieckmann,P.&Amacher,A.(200I).EnhancingPerformanceinHighRiskEnvironments,RecommendationsfortheuseofBehaviouralMarkers.Stuttgart:GottliebDaimlerundKarlBenzStiftung.

Klampfer,B.&Hausler,R.(2002).Theuseofbehaviouralmarkersinthesimulator.Proceedingsofthe251hConferenceoftheEuropeanAssociationforAviationPsychology,Warsaw,1620September2002.

14 Training of Situation Awareness and Threat Management Techniques

Amalberti, R. (in prep.) The cognitive control of dynamic situations. In P. Barach (ed.) Clambake Seminar on Human Error. Chicago.

Banbury, S., Hormann, H.-J., Soli, H. & Dudfield, H.J. (in prep.). Development and validation of novel measures of Situation Awareness to assess the effectiveness of commercial airline pilot threat management training.

Flin, R., Martin, L., Goeters, K.-M., Hormann, H.-J., Amalberti, R., Valot, C. & Nijhuis, H. (2003). Development of the NOTECHS (Non-technical skills) system for assessing pilots' CRM skills. Human Factors and Aerospace Safety, 3, 95-117.

Fowlkes, J., Lane, N., Salas, E., Franz, T. & Oser, R. (1994) Improving the measurement of team performance: The TARGETs methodology. Military Psychology, 6, 47-61.

Helmreich, R., Butler, R., Taggert, W. & Wilhelm, J. (1997). The NASA/University of Texas/Federal Aviation Administration Line/LOS checklist: A behavioural-based checklist for CRM skills assessment (Version 4.4). Austin, Tx: NASA/University of Texas/Federal Aviation Administration Aerospace Group.

Hormann, H.-J., Banbury, S., Blokzijl, C., Dudfield, H.J., Lamers, J., Lehmann, 0., Lodge, M. & Soli, H. (2003). Experimental Validation. ESSAI WP5 Workpackage Report. ESSAI/DLR&Q_QIWPRIWP512.0. EC DG-TREN. Contract No.: 2000-GRDI-10450. This page intentionally left blank

15 Non-Technical Skills Assessment in Pilot Training: Theory and Practice of the NOTECHS Method

Flin.R.,Martin,L.,Goeters,K.M.,Hormann,H.J.,Amalberti,R.,Valot,C.,andNijhuis,H.(2003).DevelopmentoftheNOTECHS(NonTechnicalSkills)SystemforAssessingPilots'CRMskills.HumanFactorsandAerospaceSafety3,95117.

Goeters,K.M.(2002).Evaluationoftheeffectsof CRMtrainingbytheassessmentofnontechnicalskillsunderLOFT.HumanFactorsandAerospaceSafety2,7186. This page intentionally left blank

Flin, R. & Martin, L. (1998) Behavioural Markers for Crew Resource Management. Report to CAA (98005). London: CAA.

Flin, R. & Martin, L. (2001) Behavioural Markers for Crew Resource Management: A survey. International Journal of Aviation Psychology, 11, 95-118.

Helrnreich, R., Butler, R., Taggart, W., & Wilhelm, J. (1997) The NASNUT/ FAA Line/LOS Checklist: A behavioural-based checklist for CRM skills assessment (Version 4.4 dated 1.2.97). Austin, Texas: NAS/UT/FAA Aerospace Group.

Holt, R., Boehm-Davis, D. & Beaubien, M. (2001) Evaluating resource management training. In E. Salas, C. Bowers & E. Edens (eds.) Improving Teamwork in Organisations. NJ: Lawrence Erlbaum.

JAA (1999) JAR-OPS. 1 Subpart N (NPA-OPS-16) Crew Resource ManagementFlight Crew. Hoofdorp, Netherlands: EC Joint aviation Authorities.

Jensen, R. (1995) Pilot Judgment and Crew Resource Management. Aldershot: Ashgate.

Klampfer, B., Flin, R., Helrnreich, R. et a! (2001) Recommendation for the use of behavioural markers. Berlin: Daimler Benz Foundation. Available as pdf document. www. psyc. abdn.ac. uk/serv02.htm.

O'Connor, P., Hormann, H.-J., Flin, R., Lodge, M., Goeters, K.-M. (2002) Developing a method for evaluating Crew Resource Management skills: A European perspective. International Journal of Aviation Psychology, 12, 263-285.

van Avermaete, J. & Kruijsen, E. (1998) The evaluation of non-technical skills of multipilot aircrew in relation to the JAR-FCL requirements. (Report NLR-CR-98443). Amsterdam: NLR.

Wiener, E., Kanki, B. & Helmreich, R. (1993) (eds.) Cockpit Resource Management. San Diego: Academic Press.
This page intentionally left blank

17 Non-Technical Skills Assessment in Pilot Training: Experimental Plan of the JAR-TEL Study

Hormann,H.J.,Fletcher,G.,&Goeters.K.M.(1998).Synthesisofculturalaspectsandtheirinfluencesoncrewbehaviour.JARTELWPl:Finalreport.ResearchreportfortheEuropeanCommission,DGVII.JARTELIDLR&DERA/WPR/1103.

Hofstede,G.(1991).CulturesandOrganisations:Softwaresofthemind.UK:McGrawHill.

Hofstede,G.(1980).Culture'sconsequences:Internationaldijjerencesinworkrelatedvalues.BeverlyHills,CA:Sage.

This page intentionally left blank

18 JAR-TEL Results: Inter-rater Reliabilities, Sensitivity and Acceptability of the NOTECHS Method

James,LR.,Demaree,R.G.&Wolf,G.(1984)Estimatingwithingroupinterraterreliabilitywithandwithoutresponsebias.JournalofAppliedPsychology,69(I),8598.

James.LR.,Demaree,R.G.&Wolf,G.(1993)rwg:Anassessmentofwithingroupinterrateragreement.JournalofAppliedPsychology,78(2),306309.

Law,R.J.&Sherman,P.J.(1995)Doratersagree?Assessinginterrateragreementintheevaluationofaircrewresourcemanagementskills.InR.Jensen(ed.)ProceedingsoftheEighthInternationalSymposiumonAviationPsychology,April.ColumbusOhio,OhioStateUniversity.

Schmidt,F.L&Hunter,J.E.(1989)Interraterreliabilitycoefficientscannotbecomputedwhenonlyonestimulusisrated.JournalofAppliedPsychology,74,368370.

Seamster,T.,&Edens,E.(1993).CognitivemodellingofCRMassessmentexpertise:Identificationoftheprimaryassessors.InL,Smith(ed.)ProceedingsoftheHumanFactorsandErgonomicsSociety371hAnnualMeeting.SanDiego:HFES.

Williams,D.M.,Holt,R.W.&BoehmDavies,D.A.(1997).Trainingforinterraterreliability:Baselinesandbenchmarks.InR.Jensen(ed.)ProceedingsoftheNinthInternationalSymposiumonAviationPsychology,April.ColumbusOhio,OhioStateUniversity.

This page intentionally left blank

19 JAR-TEL Results: Testing the Cultural Robustness of the NOTECHS Method

Amalberti,R.&Valot,C.(2001).Wp5GuidelinesforimplementationofNOTECHS.TechnicalreportJARTELIWP5/DRAFT41/MASSA.!MASSA,BretignysurOrge,15January2001.

Berry,J.W.,Portinga,Y.H.,Segall,M.H.,&Dasen,P.R.(1992).Crossculturalpsychology:Researchandapplications.Cambridge:CambridgeUniversityPress.

FAAHumanFactorsTeam(1996).TheInterfacesBetweenFlightcrewsandModernFlightDeckSystems.USFederalAviationAuthorityReport.

Helmreich,R.L.&Merritt,A.C.(1998).Cultureatworkinaviationandmedicine:National,organizationalandprofossionalinfluences.Avebury:Aldershot.

Helmreich,R.L.,Merritt,A.C.&Sherman,P.J.(1996).Humanfactorsandnationalculture.InternationalCivilAviationOrganization(!CAD)Journal,51,1416.

Helmreich,R.L.&Wilhelm,J.A.(1997).CRMandculture:National,professional,organizational,safety.InProceedingsoftheNinthAviationPsychologySymposium.Columbus:OhioStateUniversity.

Hormann,H.J.(200I).Culturalvariationofperceptionsofcrewbehaviourinmultipilotaircraft.InC.Valot&R.Amalberti(eds.)CognitiveErgonomicsinAeronautics(SpecialIssue),LeTravailHumain,64(3),pp.248268.

Hormann,H.J.,Fletcher,G.,&Goeters,K.M.(1998).SynthesisofculturalaspectsandTestingtheCultur

alRobustnessoftheNOTECHSMethod285theirinfluencesoncrewbehaviour.JARTELWPI:Finalreport.ResearchreportfortheEuropeanCommission,DGVII.JARTELIDLR&DERA/WPR/1103.

Hofstede,G.(1991).CulturesandOrganisations:Sojtwaresofthemind.UK:McGrawHill.

Hofstede,G.(1980).Culture'sconsequences:Internationaldifferencesinworkrelatedvalues.BeverlyHills,CA:Sage.

Johnston,N.(1993).CRM:Crossculturalperspectives.InE.L.Wiener,B.Kanki,&R.L.Helmreich(eds.),Crewresourcemanagement(pp.367398).SanDiego:AcademicPress.

Maurino,D.E.(1994).Crossculturalperspectivesinhumanfactorstraining:LessonsfromtheICAOHumanFactorsProgram.TheInternationalJournalofAviationPsychology,4,173181.

Merritt,A.C.(1996).Nationalcultureandworkattitudesincommercialaviation:Aculturalinvestigation.Doctoraldissertation.UniversityofTexas,Austin.

Meshkati,N.(1996).Culturalfactorsinfluencingsafetyneedtobeaddressedindesignandoperationoftechnology.ICAOJournal,51,1728.

O'Connor,P.,Hormann,H.J.,Flin,R.,Lodge,M.&Goeters,K.M.(2002).DevelopingamethodforevaluatingCRMskills:AEuropeanPerspective.InternationalJournalofAviationPsychology,12,263285.

Phelan,P.(1994).CultivatingSafety.FlightInternational,146,2224.

Sherman, P.J., Helmreich, R.L. & Merritt, A.C. (1997). National Culture and Flight Deck Automation: Results of a Multination Survey. International Journal of Aviation Psychology, 7(4), 311329.

Smith, P.B., Duggan, S., & Trompenaars, F. (1996). National Culture and the Values of Organisational Employees. Journal of Cross Cultural Psychology, 27, 231264.

Yamamori, H. (1987). Optimum Culture in the Cockpit. In H.W. Orlady & H.C. Foushee (eds.) Cockpit Resource Management Training, NASA Conference Publication 2455, 7587. Moffett Field, CA: NASA Ames Research Centre. This page intentionally left blank

21 Validation of CRM Training by NOTECHS: Results of the PHARE ASI Project

Avermaete,J.A.Gvan&Kruijsen.E.A.C.,(eds.)(1998):NOTECHSTheevaluationofnontechnicalskillsofmultipilotaircrewinrelationtotheJARFCLrequirements.NLRCR98443.

EiBfeldt,H.,Goeters,K.M.,Hormann,H.J.,Maschke,P.&Schiewe,A.(1994),DLRMitteilung9409.

Flin,R.,Goeters,K.M.,Hormann,H.J.,&Martin,L.(1998):AGenericStructureofNonTechnicalSkillsforTrainingandAssessment.Proceedingsofthe23rdConferenceoftheEuropeanAssociationforAviationPsychology,Vienna,1418September1998(reeditedinthischapter).

Hormann,H.J.(1994),FORDECApresciptivemethodforaeronauticaldecisionmaking,Proceedingsofthe21stWEAAPConference,Dublin.

This page intentionally left blank

22 Psychological Requirements and Examination Guidelines in JAR-FCL 3

Ackerman,P.L.(1988).DeterminantsofIndividualDifferencesDuringSkillAcquisition:CognitiveAbilitiesandInformationProcessing.JournalofExperimentalPsychology:General,117,3,288318.

Ackerman,P.L.&Schneider,W.(1985).IndividualDifferencesinAutomaticandControlledInformationProcessing.InR.F.Dillon&R.F.Schmeck(ed.),IndividualDifferencesinCognition,London:AcademicPress.

AmericanPsychiatricAssociation(1994).DiagnosticandStatisticalManualofMentalDisorders.FourthEdition.APA,Washington.

Binet,A.,Simon,Th.(1895).Lapsychologicindividuelle.AnneePsychologique,2,411463.

BoehmDavis,D.A.,Holt,R.W.,Hansberger.J.T.(1997).Pilotabilitiesandperformance.Paperpresentedatthe9thInternationalSymposiumonAviationPsychology,Columbus,Ohio.

Gregorich,S.E.,Helmreich,R.L.&Wilhelm,J.A.(1990).Thestructureofcockpitmanagementattitudes.JournalofAppliedPsychology,75(6),682690.

Goeters.K.M.,Maschke,P.,Klamm,A.(1998).AnExtendedJobAnalysisTechnique,theProfessionalDemandsofAirlinePilotsandImplicationsforSelection.Paperpresentedatthe23rdConferenceofEAAP,Vienna .

JAA Joint Aviation Authorities (1996/2003). Flight Crew

Licensing. Part 3 (Medical), Colorado: Global Engeneering Documents.

Johnston, N. (1996). Psychological Testing and Pilot Licensing. The International Journal of Aviation Psychology, 6 (2), 179-197.

Luftfahrt-Bundesamt (1996). Fliegerarztlicher Ausschuss (FA) Statistiken. Internal statistics. Braunschweig.

Stelling, D. (1999). Psychological evaluation of problem cases in aviation. EAAP Course material, 'Clinical Psychology' course, EAAP/JRC: lspra.

Tundo, A., Marchetti, F. Neuroses, psychoses and drug addiction in aviation personnel: A clinical experience. In K.-M. Goeters (ed.), Aviation Psychology: A Science and a Profession. Aldershot: Ashgate. This page intentionally left blank

23 Prevention and Treatment of Post-Traumatic Stress Effects

Cannon, W.B. (1929). Bodily changes in pain, hunger,fear, and rage. New York: AppletonCentury.

Flannery, R.B. (1998). The Assaulted Staff Action Program: Coping with the psychological aftermath of violence. Ellicott City, MD: Chevron Publishing.

Lazarus, R.S. (1966). Psychological Stress and the Coping Process. New York: McCrawHill.

Mitchell, J.T. & Everly, G.S. (1996). Critical Incident Stress Debriefing: An Operations Manual. Ellicott City, MD: Chevron.

Mitchell, J.T. & Everly, G.S. (2002). CISM and CISD: Evolution, effects and outcomes. In B. Raphael & J. Wilson (eds.). Psychological Debriefing.

NCPTSD (1999). Posttraumatic Stress Disorder (PTSD) and War-Related Stress. Information for Veterans and their Families. Words of Art, West-Heidelberg, Australia.

Roth, W. (1995). 'Mens sana in corpore sano. Das Anti-StreBkonzept ftir das Fliegende Personal der Bundeswehr'. Truppenpraxis, 12, 832835.

Roth, W. (1998). 'Clinical Psychology Applications in Military Aviation'. In: Goeters, K.M. (ed.): Aviation Psychology: A Science and a Profession. Proceedings of the 22nd International Conference of the European Association of Aviation Psychology, Aldershot, England: Ashgate Publishing.

Roth, W. (2001). 'Stressmanagement ftir das Fliegende Personal der Bundeswehr'. In: Puzicha, K.-J., Hansen, D., Weber, W. (Herausgeber): 'Psychologie fur Einsatz und Notfall'. Bonn: Bernhard & Graefe.

Selye, H. (1974). Stress without distress. Philadelphia: Lippincott.

24 Integration of Different Autonomic Measures into Common Indicators of 'Psychophysiological Costs'

Backs,R.W.(1995).Goingbeyondheartrate:Autonomicspaceandcardiovascularassessmentofmentalworkload.SpecialIssue:Pilotworkload:Contemporaryissues.fnternationalJournalofAviationPsychology5,2548.

Boucsein,W.(1991).ArbeitspsychologischeBcanspruchungsforschungheutccineHerausforderungandiePsychophysiologic.PsychologischeRundschau42,129144.

Cacioppo,J.T.(1994a).Socialneuroscience:Autonomic,neuroendocrine,andimmuneresponsetostress.Psychophysiology31,113128.

Cacioppo,J.T.,&UchinoB.N.,BerntsonG.G.(1994b).Individualdifferencesintheautonomicoriginsofheartratereactivity:Thepsychometricsofrespiratorysinusarrhythmiaandpreejectionperiod.Psychophysiology3,1412419.

CaldwellJ.,Hall,K.K.,&Erickson,B.S.(2002).EEGdatacollectedfromhelicopterpilotsinflightaresufficientlysensitivetodetectincreasedfatiguefromsleepdeprivation.InternationalJournalofAviationPsychology12(I),1932.

Enne,R.DieHerzfrequenzunddieStimmgrundfrequenzzurBeurteilungphysischerundpsychischerBelastungssituationen.DissertationUniversityWien,inpreparation.

Johannes,B.,Eichhorn,C.,&Fischer,F.(1994).Acomplexexperimentalassessmentforobjectivehierarchicaldescriptionofhierarchicalpsychophysiologicalbehavioura

s h u m a n r e g u l a t o r y p h e n o t y p e . P r o c e e d i n g s o f t h e ! U P S M e e t i n g G r a v i t a t i o n a l P h y s i o l o g y , B a r c e l o n a , O c t o b e r 3 7 , 1 9 9 3 . J G r a v i t P h y s i o l . 1 (1) , 7 3 7 4 .

Johannes, B., Salnitski, V.P., Gunga, H.C., & Kirsch, K. (2000). Voice stress monitoring in space possibilities and limits. Workshop Human factors in space, Tokyo, July 7-9, 1999. Aviation Space Environmental Medicine 71(9), Section II, A58-A65.

Johannes, B., Salnitski, V.P., Thieme, K., & Kirsch, K. (2003). Differences in the Autonomic Reactivity Pattern to Psychological Load In Patients with Hypertension and Rheumatic Diseases, Aviakosm i Ecolog Med 37(1), 28-42.

Kuroda, 1., Fujiwara, 0., Okamura, N., & Utsuki, N. (1976). Method for determining pilot stress through analysis of voice communication. Aviation Space Environmental Medicine 47(5), 528-533.

Lacey, J.I. (1956). The evaluation of autonomic responses: toward a general solution. Am.N.Y.Acad.Sci. 67, 125-163.

Lacey, J.I., & Lacey, B.C. (1958). Verification and extension of the principle of autonomic response-stereotypy. Amer.J.Psychol1958 71, 50-73.

Lader, M. (1983). Behaviour and Anxiety: Physiologic Mechanisms. J.Clin.Psychiatry 44(11), Sec.2, 5-10.

Lager, C. (1974). Pilot reliability. PECAB, Stockholm.

Levi, L. (1972). Stress and distress in response to psychosocial stimuli. Laboratory and real life studies on sympathoadrenomedullary and related reactions. Acta med. scand., Suppl., 528.

Magnusson, S. (2002). Similarities and differences in psychophysiological reactions between simulated and real air-to-ground missions. International Journal of Aviation Psychology 12(1), 49-61.

Nedkov, R. (1993). System for intelligent digital biosignal processing on space board. Aerospace Researches in Bulgaria, 9(10), 65-70.

Richter, P., & Grunert, P. (1991). Psychologische Beanspruchungs und ZuverHissigkeitsdiagnostik des Menschen

in komplexen Automatisierungssystemen. Wiss. Z. d. TU Dresden. 40, %, 47-51.

Richter, P., Wagner, T., Heger, R., & Weise, G. (1998). Psychophysiological analysis of mental load during driving on rural roads quasi-experimental field study. Ergonomics 41(5), 593-609.

Roscoe, A.H. (1975). Heart rate monitoring of pilots flying aircraft steep gradient approaches. Aviation Space Environmental Medicine 46, 1410-1415.

Roscoe, A.H. (1978). Stress and workload in pilots. Aviation Space Environmental Medicine 49, 630-636.

Roscoe, A.H. (1992) Assessing pilot workload: why measure heart rate, HRV and respiration? Biological Psychology 34, 259-288.

Salnitski, V.P., Bobrov, A.F., Sheblanov, V.Ju., & Johannes, B. (2001a). Profession Stress and it's influence on operator's working reliability under long-term isolation. Grigoriev, A.I. et al. (eds.) Life support problems in hermetic objects (Ru). Slovo, Moscow, 162-163.

Salnitski, V.P., Dudukin, A.V., & Johannes, B. (2001b). Evaluation of operator's reliability in long-term isolation (The 'Pilot' -Test). Baranov, V.M. (ed.) Simulation of extended isolation: advances and problems. Slovo, Moscow, 30-50.

Seleye, M. The evaluation of the stress concept 1936-1973. American Science 1973 61, 692699.

Speisman, J.C., Osborn, J., & Lazarus, R.S. Cluster analysis of skin resistance and heart rate at rest and under stress. Psychosomatic Medicine 1961 13, 333-343.

Vaic, H., & Friedrich, J., & Kolinichenko, T.B. (1981). Analyse des Flugfunkverkehrs als Beitrag zur Beurteilung der Arbeitsfahigkeit von Kosmonauten. Z Militarmed 2, 73-76.

V a i c , H . , & F r i e d r i c h , J . (1 9 8 2) . D e r E i n t l u s s v o n p h y s i s c h e r u n d m e n t a l k o n z e n t r a t i v e r B e l a s t u n g a u f d i e G r u n d f r e q u e n z d e r S p r a c h e v o n O p e r

ateuren.EinBeitragzurSprachanalyseinderLuftundRaumfahrtmedizin.ZMilitarmed1,263I.

Williams,C.E.,&Stevens,K.N.(1969).Ondeterminingtheemotionalstateofpilotsduringflight.Anexploratorystudy.AerospaceMedicine40,13691372.

Wilson,F.W.,&Oliver,C.G.(l991a).PATs:PsychophysiologicalAssessmentTestSystem.Farmer,E.(ed).Stressanderrorinaviation.AveburyTechnical:Aldershot,England,2734.

Wilson,G.F.,&Fullenkamp,P.(1991b).Psychophysiologicalassessmentofpilotandweaponsystemoperatorworkload.Farmer,E.(ed).Stressanderrorinaviation.AveburyTechnical:Aldershot,England,1525.

Wilson,G.F.(2002).Ananalysisofmentalworkloadinpilotsduringflightusingmultiplepsychophysiologicalmeasures.InternationalJournalofPsychology12(1),318.

Wittels,P.,Johannes,B.,Enne,R.,Kirsch,K.,&Gunga,H.(2002).Voicemonitoringtomeasureemotionalloadduringshorttermstress.EurJApplPhysiol.87,278282.

Vogel,J.L.(1995).Relationshipbetweenaviationphysiologyandaviationpsychology.Fuller,R.etal.(eds.)Humanfactorsinaviationoperations.AveburyAviation:Aldershot,England,235240.

Eurocontrol-Hera (2003) The Human error in ATM Technique (HERA JANUS). HRS/HSP002-REP-03. Eurocontrol. Brussels.

Eurocontrol-pHera (2003) A method for predicting Human Error in ATM (HERA Predict). HRS/HSP-002-REP-07. Eurocontrol. Brussels.

Eurocontrol-Shape (2003) The Impact of Automation on Future Controller Skill Requirements and a Framework for SHAPE. Eurocontrol. Brussels.

Eurocontrol-Tokai (2003) Toolkit for ATM Occurrence Investigation. Eurocontrol. Brussels. Available at:

Hollnagel, E. (1998) Cognitive Reliability and Error Analysis MethodCREAM. Elsevier. New York, Amsterdam. (ISBN 0-08-042848-7.)

IAEA (2001) Guidelines for describing Human Factors in the IRS (Human actions and related causal factors and root causes) IAEA. Vienna (IAEA-14-CS-10).

IAEA (2001) IRS Study on Incidents Caused by Loss Of Corporate Knowledge And Memory (Phase II In depth analysis of selected events). IAEA. Vienna (IAEA14CS04101).

Kahneman, D. & A. Tversky (1979) Prospect Theory: An Analysis of Decision Under Risk. Ecometrica 47, pp. 263291

Kanse, L. and van der Schaat: T. (2000). Recovery from failures understanding the positive role of human operators during incidents. In by D. de Waard, C. Weikert, J. Hoonhout and J. Ramaekers (eds.), Human System Interaction: Education, Research and Application in the 21st Century. Shaker Publishing: Maastricht, Netherlands.

Linsenmaier2003Achievingconsistentanddetailedincidentanalysesforacommoninterdisciplinaryhumanreliabilitydatabaseastudyinaviation.lEA2003.Seoul/Korea.

OECDNEA(2002)StrengtheningthelinkbetweenHRAanddata.WorkshopoftheOECD/NEA.GRS.MunichIGermany.

Reason,J.(1990)HumanError.CambridgeUniversityPress.Cambridge.

Shorrock,S.T.(1997).TheDevelopmentandEvaluationofTRACEr:ATechniquefortheRetrospectiveAnalysisofCognitiveErrorsinAirTrafficControl.MSc(Eng)Thesis:TheUniversityofBirmingham,September1997.

Strater,0.&Bubb,H.(2003)DesignofSystemsinSettingswithRemoteAccesstoCognitivePerformance.In:Hollnagel,E.(ed.)HandbookofCognitiveTask.Design.Erlbaum.NewJersey.

Strater,0.&Kirwan,B.(2002)DifferencesbetweenHumanReliabilityApproachesinNuclearandAviationSafety.IEEESeventhConferenceonHumanFactorsandPowerPlantsNewCentury,NewTrends.September1519,2002.Scottsdale,Arizona.

Strater,0.&Reer,B.(1999)AComparisonoftheApplicationoftheCAHRmethodtotheevaluationofPWRandBWReventsandsomeimplicationsforthemethodologicaldevelopmentofHRA.In:Modarres,M.(ed).PSA'99RiskInformedPerformanceBasedRegulation.AmericanNuclearSociety.LaGrangePark,Illinois,USA.(ISBN0894486403.)

Strater,0.(1997)InvestigationsontheInfluenceofSituationalConditionsonHumanReliabilityinTechnicalSystems.In:Seppala,P.,Luopajarvi,T.,Nygard,C.&Mattila,M.(eds.)Proceedingsofthe13thTriennialConferenceoftheInternationalErgonomicAssociation.June1997.TampereIFinland.Vol.3.pp.76ff.

Strater,0.(2000)EvaluationofHumanReliabilityontheBasisofOperationalExperience.GRS170.GRS.KolnIGermany.(ISBN3931995372)At:www.grs.delgrs170.htm.

Strater,0.(2004,inPress)ZuverlassigkeitmenschlicherHandlungenundSystemgestaltung.In:Zimolong,B.&Konrad,U.(eds.)Ingenieurspsychologie.EnzyklopiidiederPsychologic.Hogrefe.Gottingen.

Strater,0.,Dang,V.,Kaufer,B.&Daniels,A.(2003)OntheWaytoAssessErrorsofCommission.InStrater,0.(ed.)HRAdataissuesanderrorsofcommission.ReliabilityEngineeringandSystemSafety.VolSpecialIssue.Elsevier.

Strater,0.,Isaac,A.&VanDamme,D.(2002)ConsiderationsontheElementsoftheQuantificationofHumanReliability.In:OECDNEA(ed.)StrengtheningthelinkbetweenHRAanddata.WorkshopoftheOECD/NEA.GRS.MunichIGermany.

USNRC(2000)TechnicalBasisandImplementationGuidelinesforATechniqueforHumanEventAnalysis(ATHEANA).NUREG1624.NRC.WashingtonDC.Rev.1.

VanDamme,D.(1998)HumanFactorsintheinvestigationofAccidentsandIncidents.HUM.ETI.ST13.3000REP02.Eurocontrol.Brussels.

Wilpert, Fahlbruch, Miller (1998) Sicherheit durch Organisationales Lemen. ATW 43, 1998.

AviationSafetyCouncil(2001).Crashedonapartiallyclosedrunwayduringtakeoff,SingaporeAirlinesFlight006,Boeing747400,9VSPK,CKSAirport.Taoyuan,Taiwan,October31,2000.(ReportNumberASCAAR0204001).Taiwan,ROC.

BHP.(2000).IncidentCauseAnalysisMethod.Melbourne:Author.

BristolRoyalInfirmaryInquiry.(2001,July).London:Author.

BureauofAirSafetyInvestigation.(1995).InvestigationReport9301743:Piper,PA31350Chieftain,Young,NSW,11June1993.Canberra:Author.

BureauofAirSafetyInvestigation.(1996).InvestigationReport9403038:Boeing747312VHINH,Sydney(KingsfordSmith)Airport,NSW,19October1994.Canberra:Author.

ColumbiaAccidentInvestigationBoard.(2003).ColumbiaAccidentInvestigationBoardReport,Volumel.Washington,DC:Author.

Dekker,S.W.A.(2002a).Reconstructinghumancontributionstoaccidents:thenewviewonhumanerrorandperformance.JournalofSafetyResearch,33,371385.

Dekker,S.W.A.(2002b).Thefieldguidetohumanerrorinvestigations.Aldershot,UK:Ashgate.

Fennell,D.(1988).InvestigationintotheKing'sCrossundergroundfire.DepartmentofTransport,London:HMSO.

Free,R.J.(1994).Theroleofproce

dural violations in railway accidents. Unpublished PhD thesis, University of Manchester, UK.

Hayward, B. J., Lee, R. B., Hobbs, A., & Pollack, K. (1998). Human factors in accident investigation and prevention. In K M. Goeters (ed.), Aviation psychology: A science and a profession. Aldershot, UK: Ashgate.

Helmreich, R. L. (1993). Anatomy of a system accident: The crash of Avianca Flight 052. Austin, TX: NASNUT/FAA Aerospace Crew Research Project.

Helmreich, R. L., & Foushee, H. C. (1993). Why crew resource management? Empirical and theoretical bases of human factors training in aviation. In E. L. Wiener, B. G. Kanki, & R. L. Helmreich (eds.), Cockpit resource management. (pp. 345). San Diego: Academic Press.

Helmreich, R. L., Merritt, A. C., & Wilhelm, J. A. (1999). The evolution of Crew Resource Management training in commercial aviation. International Journal of Aviation Psychology, 9(1), 1932.

Helmreich, R. L., & Merritt, A. C. (2000). Safety and error management: The role of Crew Resource Management. In B. J. Hayward & A. R. Lowe (eds.), Aviation resource management, Volume I. Aldershot, UK: Ashgate.

Hidden, A. (1989). Investigation into the Clapham Junction railway accident. London: Department of Transport: HMSO.

Johnston, A. N. (1991). Organisational factors in human factors accid

entinvestigation.Proceedingsof the6thInternationalSymposiumon AviationPsychology(pp.668673). Columbus,Ohio:OhioStateUnivers ity.

Johnston,A.N.(1996).Managingri skinflightoperations.InB.J.Hay ward&A.R.Lowe(eds.),Appliedavi ationpsychology:Achievement,ch angeandchallenge.Aldershot,UK: AveburyAviation.

Lee,R.(1996).Aviationpsycholog yandsafety:Implementingsolutio ns.InB.J.Hayward&A.R.Lowe(eds.),AppliedAviationPsychology:Ac hievement,ChangeandChallenge.A ldershot,UK:AveburyAviation.

Maurifio,D.E..Reason,J.,Johnst on,N.,&Lee,R.B.(1995).Beyondav iationhumanfactors.Aldershot,U K:AveburyAviation.

Moshansky,V.P.(1992).Commissio nofinquiryintotheAirOntariocra shatDryden,Ontario:FinalReport .Ottawa:CanadianMinistryofSupp lyandServices.

Norman,D.A.(198I).Thecategoris ationofactionslips.Psychologic alReview,88,115.

Paries,J.(1996).Evolutionofthe aviationsafetyparadigm:Towards systemiccausalityandproactivea ctions.InB.J.Hayward&A.R.Lowe(eds.),Appliedaviationpsycholog y:Achievement,changeandchallen ge.Aldershot,UK:AveburyAviatio n.

Paries,J.(2000).Amultilayermod elforincidentreportingandanaly sissystems.InB.J.Hayward&A.R.L owe(eds.),Aviationresourcemana gement,VolumeI.Aldershot,UK:As hgate.

Rasmussen,J.(1983).Skillsrulesandknowledge:Signals,signsandsymbols,andotherdistinctionsinhumanperformancemodels.IEEETransactionsonSystems,ManandCybernetics,Vol.SMCI3(3),257266.

Rasmussen,J.(1987).Thedefinitionofhumanerrorandataxonomyfortechnicalsystemdesign.InJ.Rasmussen,K.Duncan,&J.Leplat(eds.),Newtechnologyandhumanerror.Toronto:Wiley&Sons.

Reason,J.(1990).Humanerror.NewYork:CambridgeUniversityPress.

Reason,J.(199I).Identifyingthelatentcausesofaircraftaccidentsbeforeandaftertheevent.Proceedingsofthe22ndJSASJAnnualAirSafetySeminar,Canberra,Australia.Sterling,VA:ISASI.

Reason,J.(1993).Organisations,corporatecultureandrisk.Proceedingsof22ndTechnicalConference,Humanfactorsinaviation.Montreal:lATA.

Reason,J.(1997).Managingtherisksoforganizationalaccidents.Aldershot,UK:Ashgate.

SafetyWiseSolutions&DedaleAsiaPacific.(2002).!CAMIncidentInvestigationReferenceGuideandWorkbook.Melbourne:Authors.

Sheen,Mr.Justice(1987).MVHeraldofFreeEnterprise.ReportofCourtNo.8074FormalInvestigation.London:DepartmentofTransport:HMSO.

ShellInternationalExploration&ProductionB.V.(1994).TripodBetaHSEManual(Vol.3:EP950321).TheHague,Netherlands:Author.

Shappell,S.A.,&Wiegmann,D.A.(2000).Thehumanfactorsanalysisandclassificationsystemf!FACS(DOTIFAAIAM0017).Washington,DC:FAA.

SingaporeAirlines&DedaleAsiaPacific(200I).SIACrewResourceManagement.Singapore:Authors.

Wiegmann,D.A.,&Shappell,S.A.(2003).Ahumanerrorapproachtoaviationaccidentanalysis:Thehumanfactorsanalysisandclassificationsystem.Aldershot,UK:Ashgate.